The How and Why of the Automobile

A SERIES OF PRACTICAL TALKS ON THE MODERN MOTOR CAR

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PREFACE.

IN submitting this book for the consideration of its readers, the author wishes to impress upon them that, while he has had some experience with motor vehicles yet he does not desire to pose in any way as an authority on the subject, but rather as a sort of get-over-on-your-side-of-the-fence-and-talk-with-you-and-not-at-you "coach."

The following articles, some of which have appeared before in serial form, were written first to serve as lesson papers for a Motor School with which the writer was associated, and later revised, enlarged and edited into their present shape.

An effort has been made to avoid wherever possible the use of any technical terms which would tend to make an explanation difficult for the novice to understand, and further the author has, wherever feasible, introduced homely and familiar examples which it is hoped will render more clear the seemingly complicated mechanism of the motor car.

The author desires to acknowledge the assistance derived from the various Motor Papers, and also from the catalogues and literature which the Automobile and Motor Car Accessories Companies have been kind enough to place at his disposal. He would also gratefully acknowledge his deep obligation to Mr. Frederick L. Smith and Mr. Angus Smith, of the Olds Motor Works, for their kindly interest and assistance in the preparation of the book, Mr. E. J. Stoddard, for his expert advice on difficult technical points, Mr. J. E. Homans, Mr. H. E. Coffin and Mr. L. A. Pratt, for their criticisms and helpful suggestions.

FAY L. FAUROTE.

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CONTENTS.

THE HOW AND WHY OF THE AUTOMOBILE

A SERIES OF PRACTICAL LESSONS

By Fay L. Faurote

INTRODUCTION

GENERAL THEORY OF INTERNAL COMBUSTION ENGINES. People in general who are not familiar with the theory of the gas engine are very apt to

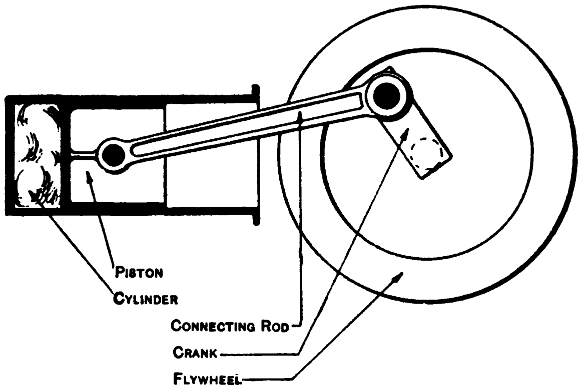


FIGURE 1.

believe that there is something mysterious about it which makes its construction and operation so complicated that they are incapable of understanding it. This is really not true. As far as the theory is concerned nothing is more commonplace and more easily understood.

If someone should tell you that nearly everyone has probably at some time or other in his life operated a gas engine you would be inclined to think that he was a candidate for an insane asylum. But let us see. Have you not at some time in your life shot off a rifle or a revolver? Did you realize at the time that the weapon in your hand was nothing more or less than one form of gas engine? Probably this may be shown to the best advantage by considering the operation of an old "muzzle loader." You will remember that in order to load the gun the powder and bullets were put into the muzzle then rammed down or compressed by a ramrod, fired by a cap placed under the hammer and finally the barrel cleaned out again by means of a rag fitted on the other end of the ramrod.

Introduction of charge.	Explosion of charge.
Compression of charge.	Cleansing of barrel.

This same set of conditions is effected in a gas engine by the four strokes of the piston.

Suction stroke - -	Introduction of gas.
Compression stroke -	Compression of gas.
Working stroke - -	Explosion of gas.
Exhaust stroke -	Removal of burnt gases.

In order to carry the comparison further, let us suppose that we are able to connect the bullet with some sort of a rod so that its energy is converted into rotary motion and used to turn a wheel. Then, instead of using all this force to carry itself through the air it would only travel a short distance, and would store up its energy in the revolving wheel. Last, if we could supply a simple mechanism which would introduce and fire new charges at regular intervals, you can see that our wheel would be kept in

motion and the power developed could be used for driving purposes.

Now, having considered one of the specific cases, let us look into the general theory upon which the internal combustion engine works. The general theory upon which any heat engine operates is, that a gas when heated expands and consequently either increases its

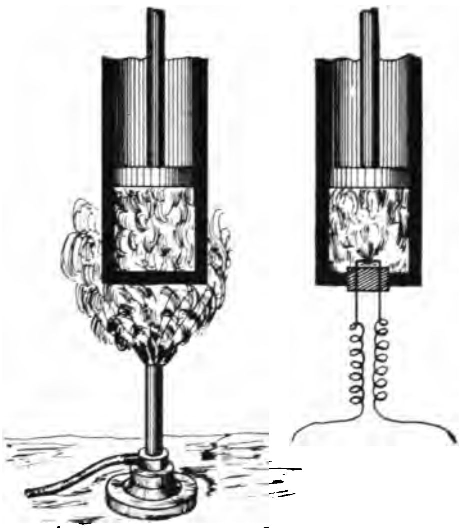


FIGURE 2.

volume or its pressure, according as the walls of the containing vessel move or remain fixed.

Thus it will be seen that if any gas is enclosed in the vessel (as shown in Fig. 2) and heated by means of a jet placed underneath, the contents will be raised in temperature, and in trying to accommodate themselves to a new condition will, if the volume is not allowed to change, exert an increased pressure in all directions on the walls or if the volume is allowed to change by a movement of the piston, do work on the crank shaft.

We know, then, that if a certain volume of gas is heated it will rise in pressure, and can be made to do work by allowing this pressure to be applied behind the moving piston, that is, the heat in the gas will be converted into mechanical energy. In the internal combustion motor this heat is furnished by the combustion of a fuel, such as gasoline or alcohol vapor or natural gas. In order to bring the contents of the cylinder to a temperature where they will burn, an electric spark is introduced to ignite the mixture.

It makes no difference as far as results are concerned whether the gases are heated from some outside agency, as in the case of the steam engine, or are made to furnish their own heat as in the case of the internal combustion engine, but when the question of efficiency is considered, the internal combustion engine is superior. In the steam engine there is a loss of efficiency, first in the boiler, then in the piping and finally in the engine, while in the gas engine practically the only loss is in the engine itself.

HISTORY OF DEVELOPMENT. As soon as it was found that more work could be obtained from the same amount of fuel by burning it in the engine cylinder instead of burning it under boilers and using the steam as a medium to transfer the energy, the construction of internal combustion engines began.

Whenever an attempt has been made to design a new machine, it has been the tendency almost invariably to copy some part or parts from similar familiar machines. Consequently, it came about very naturally that the first gas engine builders followed steam engine construction to a great extent. For that reason some of the earliest forms were double acting, that is, the

gases were allowed to act on both sides of the piston. The trouble with this construction was that the piston became very highly heated and frequently stuck in the cylinder. In order to do away with this the gas was allowed to act only on one side of the piston, the other end of the cylinder being left open to the air. In making this change, the piston rod, which is a rod running from the piston to a sliding guide called a cross-head, was done away with and the connecting rod fastened directly to the piston pin instead of to the cross-head. This type of piston is what is known as a "trunk" piston. This arrangement, however, is not as satisfactory as the double acting engine because the impulses come only on one side of the piston and the vibration consequently is very much greater. Nevertheless the smaller number of parts and the fact that the piston can be cooled easier has made this construction almost universal practice.

FUELS USED. Various substances were used to produce the explosive mixture, such as gunpowder, gasoline, kerosene, benzine, ether, alcohols and various other compounds, known to be readily volatile. One by one these were eliminated either on account of deposits which they left in the cylinder after combustion, or difficulty in getting perfect mixtures or considerations of price, until now only gasoline and kerosene are used to any great extent. The recent passage of the denatured alcohol bill, however, will affect the fuel problem quite materially and will no doubt result in the use of alcohol to a large extent as soon as its characteristics are generally known.

THE FOUR-STROKE CYCLE MOTOR

THE FOUR-STROKE CYCLE. The four-stroke cycle, as the name implies, requires four strokes of the pis-

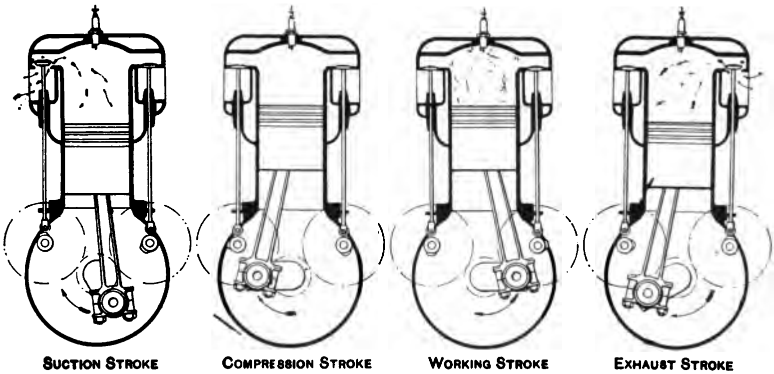


FIGURE 3.

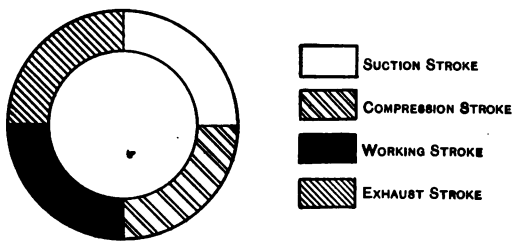


FIGURE 4.

DIAGRAM SHOWING SEQUENCE OF STROKES IN FOUR-STROKE CYCLE MOTOR.

ton to transform the heat of the acting gas into its mechanical equivalent of work. That is, while the working stroke occupies only one-quarter of the total operation, yet the three extra strokes are required to

prepare the engine for a duplicate set of operations.

Let us suppose that a crank is attached to the main shaft so that the engine may be turned over by hand in the direction indicated by the arrow. Then, as the piston starts in a downward direction, you will notice that the inlet valve will be opened by the suction, created by the increase in volume and the fresh mixture will rush into the cylinder. As soon as the piston starts to return, the inlet valve closes and the imprisoned vapor is compressed by the upward movement of the piston from a volume equal to the total volume to a volume equal to the "clearance space." The compression produced varies from 50 to 120 pounds, according to the design of the cylinder. Now, when the contents have reached this, their smallest volume, the charge is fired by means of an electric spark and the piston begins its only effective stroke, namely, the working stroke. This continues until the piston nearly reaches the extreme lowest position. At this point the exhaust valve, which has hitherto remained closed, is opened by means of a valve rod, actuated by a cam and the waste gases are allowed to escape into the atmosphere. This discharge, aided by the upward pressure of the piston, continues during all of the fourth or last stroke so that at the beginning of the next stroke of the cylinder is practically empty and ready to receive its new charge. Of course the details of these series of changes may be brought about in many ways, and they are varied according to the judgment of the designer.

ADVANTAGES OF FOUR-STROKE CYCLE MOTOR

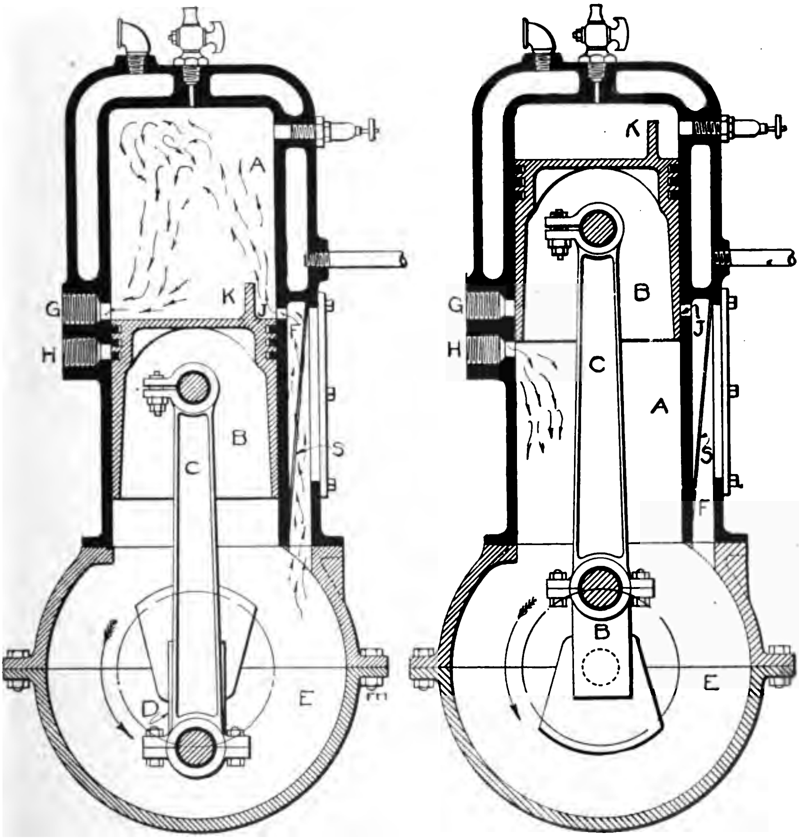
1. Ability to change time of opening and closing of valves, thus making sure that the cylinder receives its proper amount of gas and discharges it at the proper time.
2. The area of opening of valves may be made any size desired by simply varying lift.
3. Motor may be adjusted for any set of conditions.

DISADVANTAGES OF FOUR-STROKE CYCLE MOTOR

1. Cam shafts, cams and other valve mechanisms must be used. These of course have to be driven by the engine itself and consequently subtract a certain amount of power from what would otherwise be its output.
2. More working parts to keep repaired and adjusted.

THE TWO-STROKE CYCLE MOTOR

THE TWO-STROKE CYCLE. Fig. 5 represents two sectional views of the type of two-stroke cycle motor generally used for automobile work. The operation of this motor is as follows:



FIRST STROKE SECOND STROKE.

FIGURE 5.

If it is assumed, as in the case of the four-stroke cycle motor, that the engine is turned over by hand in the direction indicated by the arrow, you will notice that as the piston moves up it will uncover a port (H), allowing the gasoline vapor from the mixing chamber to enter the crank case. As soon as the piston moves down again, a port (J) will be disclosed which will allow the mixture which has just been compressed, to from 5 to 15 pounds, to rush through a "by-pass" (F), into the "combustion chamber" or upper part of the cylinder. Now, as the piston moves up again on its next stroke, this charge is compressed still more (60 lbs. to 80 lbs.), then as the piston reaches its uppermost position the charge is ignited and the engine begins to work under its own power. The gases continue to act on the piston until nearly the end of the stroke is reached, when you will notice, by referring to the drawing, the exhaust port (G) is passed. At this point the burned gases rush out into the air. You will also notice that in order to aid the discharge and to fill the cylinder again, as the piston travels a little further down, the inlet port will be again uncovered and the next charge, which has meanwhile been taken into the crank case and compressed, will enter the cylinder, forcing the exhaust gases out. In order to prevent the vapor which has just entered the cylinder from traveling straight across and out through the exhaust port, thus wasting a portion of the fuel, a "baffle plate" (K) is cast on top of the piston which deflects the gases toward the top of the combustion chamber, producing a sort of whirling action which tends to scavenge the cylinder most thoroughly. A

little study of the illustration will make this operation plain.

The methods of transferring the gases from the outside air into the crank case and from one chamber to the other, varying according to the ideas of the designer and results to be obtained.

In order to prevent the burning gases from traveling

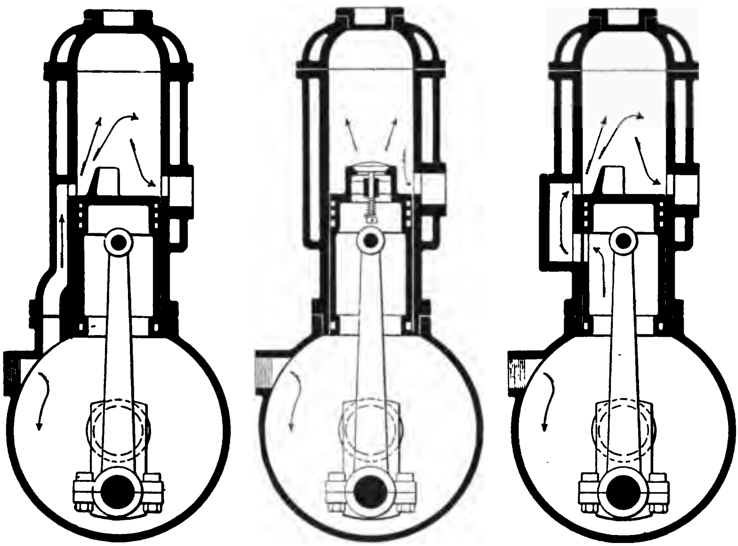


FIGURE 6—THREE DIFFERENT TYPES OF TWO-CYCLE MOTORS.

back into the crank case and igniting the gas there, thus producing a "back explosion," a wire gauze (S) is placed in the "by-pass." This wire gauze acts on the principle of the Davy or miner's lamp, that is, it allows the gases to pass through, but will not allow a flame to ignite them on the other side. The reason for this is that the gauze conducts the heat away so rapidly that the temperature is not allowed to rise to a point where the gas will be fired.

ADVANTAGES OF TWO-STROKE CYCLE MOTORS

1. The same size motor, that is, the same diameter of cylinder and the same stroke, ought to give very nearly twice the horse-power that the same size four-stroke cycle motor would develop, due, of course, to the

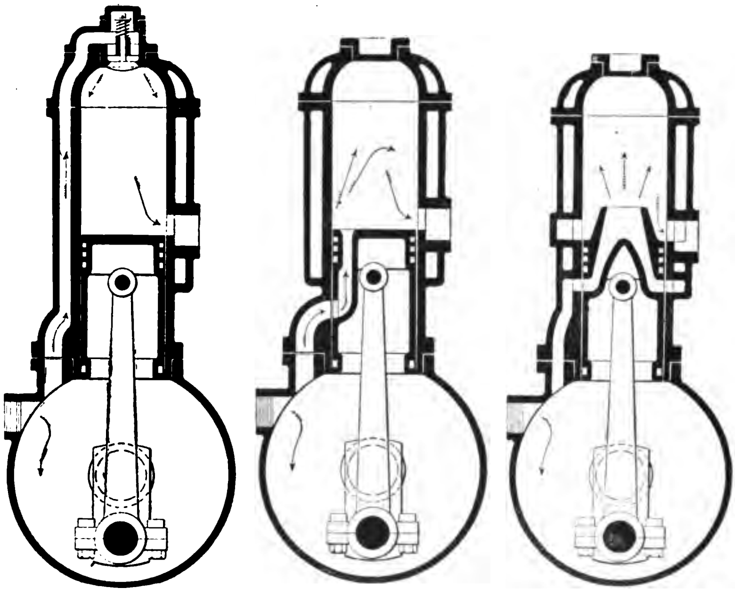


FIGURE 7—TWO-CYCLE MOTORS.

fact that there will be an explosion every revolution, whereas in the latter type, there is only one to every two revolutions of the fly wheel.

2. Absence of all valves and valve mechanisms.

3. Absence of cam shaft and cam shaft gears. The only mechanism to be operated mechanically is the commutator, and that, ignition being required every revolution, may be placed on the main shaft. In some

cases the piston itself forms a part of the ignition apparatus.

4. Less vibration, due to the fact that the impulses follow each other twice as fast as in the four-stroke cycle type, and hence there is a more uniform effort on the crank shaft.

5. Less weight of fly wheel as energy only has to be stored up for one stroke instead of three.

DISADVANTAGES OF TWO-STROKE CYCLE MOTOR

1. The fresh charge is very likely to be wasted through the exhaust port or the opposite condition may occur, that is, a large amount of burned gas may be left in the cylinder, thus giving a weak mixture.

2. The ports must be very accurately designed as the opening and closing of ports cannot be regulated after the engine is once set up. (Note.—This is not absolutely true in all cases, because several types have been designed in which valves have been used, so that certain conditions may be altered.)

3. Motor may lack power at certain speeds, as a compromise has to be made in designing the motor, so that it will run best at its normal rating.

4. Compression usually is not as high as that used in four-stroke cycle type and consequently its efficiency may not be as great.

MOTOR DESIGN

THE CYLINDER. The cylinder of a motor is that part in which the combustion takes place, that is, referring to the comparison made in the introduction, it is the barrel of the gun. It is made of cast iron, and

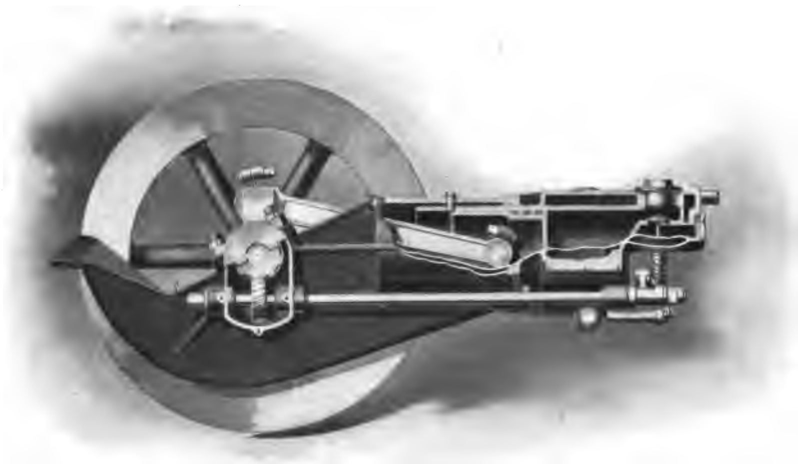


FIGURE 8—A SINGLE CYLINDER MOTOR.

includes beside the cylinder proper the valve chambers and water jacket. In addition to these there is always provision made for the introduction of a spark plug or other ignition device. The general form of the casting depends upon the type of engine for which it is used. Both single and multiple cylinder forms are

shown in the illustrations. The general structure may be easily seen, and will require no detailed description. There are several points in cylinder construction, however, which should be considered by one in selecting a car. One of the most important of these is its

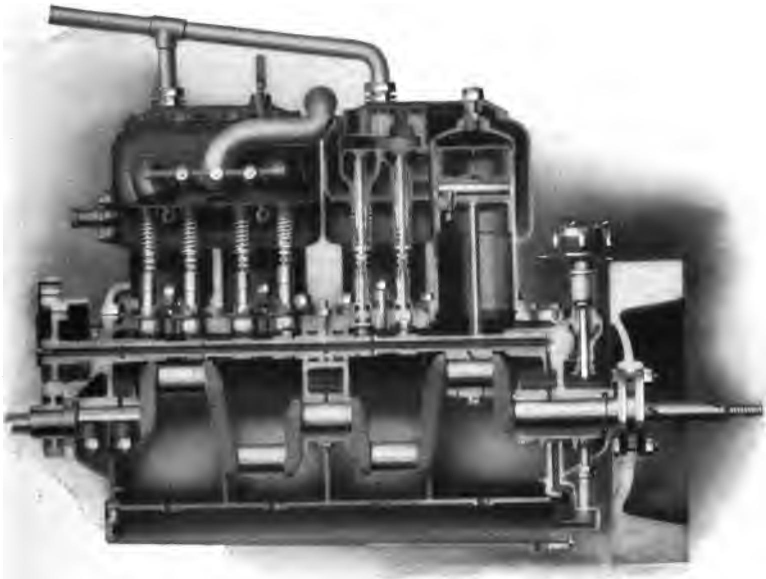


FIGURE 9—A FOUR CYLINDER MOTOR.

accessibility. It is absolutely essential that the valves shall be in such a position as to be readily examined and "ground in" when necessary.

The water jacket, also, should be of ample size, and permit of thorough inspection, as it sometimes becomes necessary to remove foreign substances which are occasionally deposited between the walls. The water inlet and outlet pipes should be perfectly free and so

situated that no "air spaces" or "steam pockets" which would interfere with the circulation of the cooling water, can be formed.

The inside of the cylinder, also, should receive care-

FIGURE 10—A TWIN CYLINDER CASTING.

FIGURE 11—A SINGLE CYLINDER CASTING.

ful attention. It should be "bored out" round, and ground to exact size, so that the piston rings can be accurately fitted, and no leakage of compression result.

VALVES AND VALVE MECHANISM. Having explained the construction and use of the cylinder, let

us now take up the question of valves and valve mechanism.

You can see that in order to introduce and release charges of gas in a cylinder, it is necessary to provide some means of opening and closing holes or "ports" in the cylinder walls. This is done by means of valves. A valve is nothing more or less than a plate that covers and uncovers a passage leading into the cylinder.

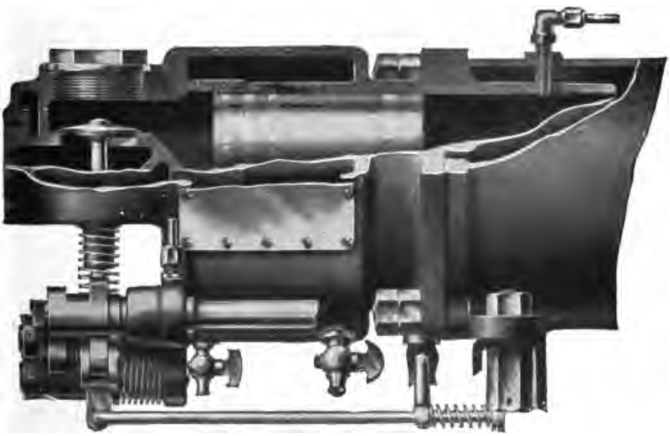
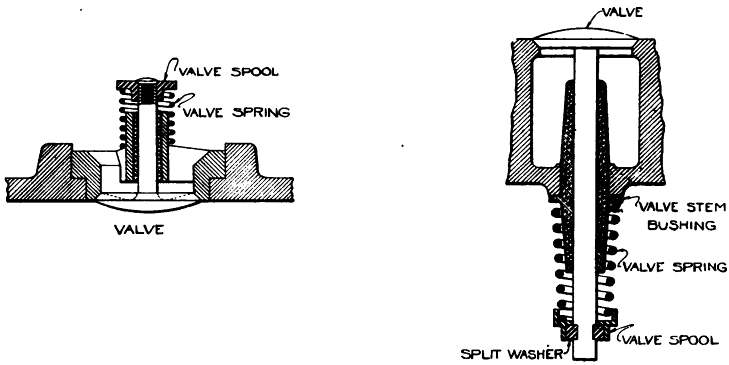


FIGURE 12 END OF CYLINDER SHOWING VALVE AND VALVE CHAMBER.

However, a simple plate will not make a joint tight enough to hold the pressure within the cylinder, consequently a slighty different form has to be used. Fig. 12 shows a typical form of valve. The size and lift of valve is determined by the size of the cylinder, and the speed at which the motor is to be run. For example, assuming that you have a certain volume to be filled each stroke, the valve must have sufficient size and opening to allow this amount of gas to enter without retarding its passage to any great extent. There-

fore, knowing the velocity at which the gas travels, and the number of times the cylinder must be filled per minute, it is a comparatively easy matter to design the valve accordingly. Naturally, the velocity of the incoming and outgoing gases is different, and, therefore, both valves are not usually given the same lift. The diameters, however, are usually made the same so that the valves are interchangeable.



SUCTION INLET VALVE MECHANICAL VALVE

FIGURE 13.

Inlet valves are of two kinds—automatic and mechanical.

THE AUTOMATIC OR SUCTION INLET. By an automatic valve we mean one which is operated by means of the suction created in the cylinder by the downward movement of the piston. This form of valve is held on its seat by means of a light spring whose tension is so adjusted that a slight decrease in pressure inside of the cylinder will cause it to open inwardly, thus allowing the gas to rush in and make up for the deficiency.

THE MECHANICAL VALVE. The mechanical valve is provided with a very stiff spring which keeps it on its seat until forced to open by means of a cam actuated by the engine itself. Thus, you see, that one is automatic while the other is positive in its action; the former opens only when the condition of the cylinder allows its operation, while the latter opens and closes always at stated intervals in the cycle. Naturally, each has its advantages and disadvantages, and each its reasons for existence.

ADVANTAGES OF AUTOMATIC INLET

1. The valve stays open until the cylinder has received enough gas so that the pressure inside is equal to the atmospheric pressure or nearly so.
2. It requires no mechanism to operate it.
3. It is cheaply constructed, and easily removable.

DISADVANTAGES OF AUTOMATIC INLET

1. This type of valve is rather noisy.
2. It is very likely to stick on its seat.
3. Tension of the spring may not be properly adjusted, and consequently the cylinder will not receive its proper charge.

~~DIS~~ADVANTAGES OF THE MECHANICAL INLET

1. It is positive in its action. Always opening and closing at the proper time, providing the valve timing is correct.
2. It cannot stick on its seat if valve mechanism is working perfectly.

DISADVANTAGES OF THE MECHANICAL INLET

1. Owing to the fact that it is very hard to calculate the exact time the valve should open and close, the above conditions are not always realized.

2. It must be operated by some form of valve mechanism, and this, of course, introduces extra bearing surfaces, levers, and rods which increase the friction loss, and require more or less attention.

3. The timing of the valves may be changed owing to the fact that cams and rods wear, and thus motor may lose power from this source.

EXHAUST VALVES. Exhaust valves must of necessity be mechanically operated for the reason that they are always opened against a comparatively high pressure.

THE MUFFLER. A muffler, as the name indicates, is a device which is connected to the exhaust pipe of a motor, used for deadening the noise of the outcoming gases, so that by the time they reach the open air any disagreeable sounds will be eliminated. It usually consists of a series of chambers made up in such a way that the gas is allowed to expand first in one, and then in another, passing through small holes so that the pressure decreases gradually. Instead of hearing a sharp report at every explosion of the engine one merely notices a purring noise caused by a continuous flow of the gas. The devious passage and the succeeding increasing and decreasing volumes act on the same principle as "baffle plates," and serve to do away with the force of the explosion. A muffler, of course, produces a certain "back pressure" upon the engine, but if the muffler is properly designed this should not decidedly affect the power of the motor.

VALVE MECHANISM. Figs. 14 and 15 shows typical forms of valve mechanisms, a brief study of which will

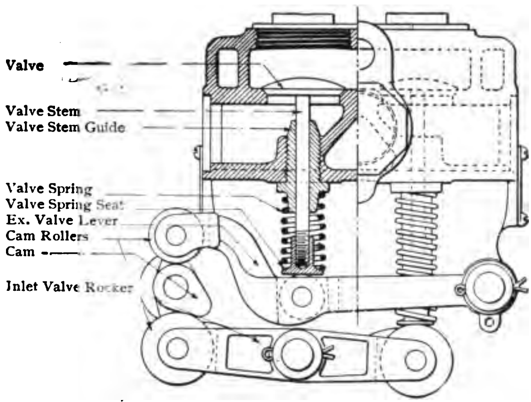


FIGURE 14—SINGLE CYLINDER VALVE PARTS.

make clear the various functions of the component parts. As you will remember, in the four-stroke cycle

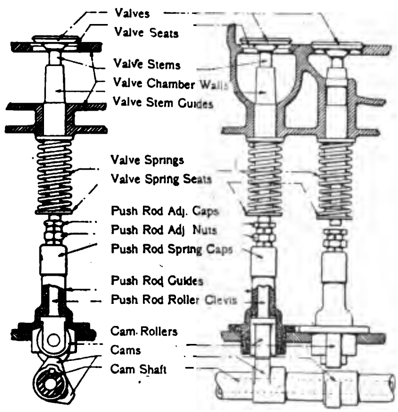


FIGURE 15—FOUR CYLINDER VALVE PARTS.

motor, the charge is taken in every other revolution, so that the valves open only every fourth stroke. Thus,

the cam shaft, which operates them, should run only one-half as fast as the main shaft of the engine. In order to bring this about, the cam shaft, or "half time" shaft, as it is sometimes called, is geared down

TYPES AND METHODS OF OPERATING VALVES.

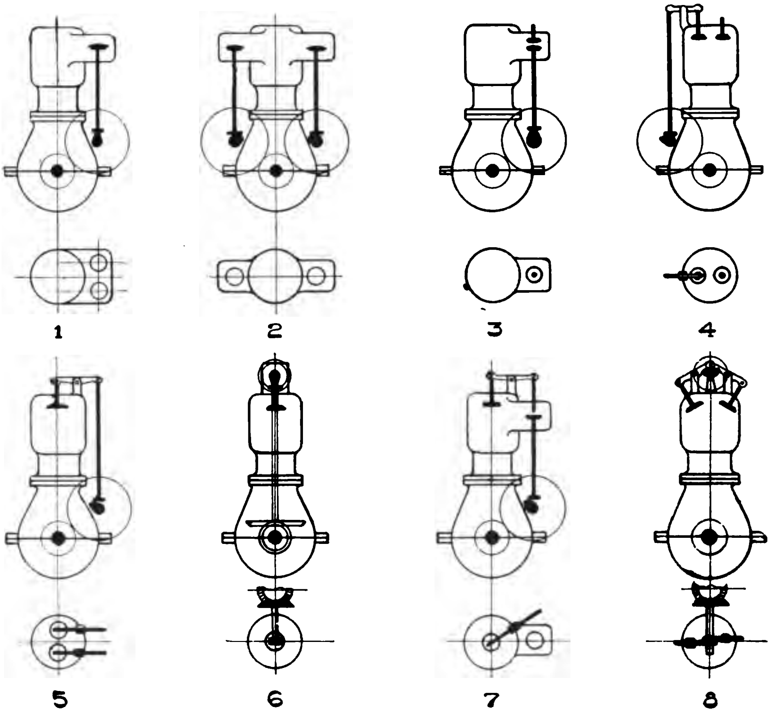


FIGURE 16.

by means of either worm or spur gears, to run at one-half the speed of the motor.

METHOD OF PLACING VALVES. Figure 11 shows various methods of placing and operating valves. In No. 1 both valves are mechanically operated and run

from the same cam shaft. No. 2 is the same except that the valves are placed on opposite sides of the cylinder, and two cam shafts are used. No. 3 shows an automatic inlet, and a mechanical exhaust. No. 4 illustrates a form where both valves are placed in the head, the inlet being of the automatic type, and the exhaust mechanically operated. No. 5 is the same, except that both are mechanical. In No. 6 both are mechanical valves, actuated by a cam shaft running across the top of the cylinder, and this in turn being operated by means of bevel gears from the main shaft. No. 7 is similar to No. 4, with the exception that only one valve is placed in the head of the cylinder. No. 8 shows a slight modification of No. 6. This, of course, only applies to vertical cylinders, but the arrangements of horizontal engine valves may be noted in some of the illustrations.

VALVE TIMING. Nothing, unless it is the quality of the fuel used, can have more influence on the power and working of an engine than the valve timing. For this reason engineers have been devoting a great deal of study to this particular problem, but as yet even the best authorities are not agreed on just when valves should open and close, so that at best the present practice is but a compromise. Experience has proved to be the best teacher, and now every motor is carefully tested until somewhere near the correct result is obtained, and then all engines of this design are built and timed accordingly.

The points of opening and closing of valves are designated in two ways: either in terms of degrees around the fly wheel, or distance moved by the piston in the cylinder. As it is much easier, after the motor

has been assembled, to determine the position of the piston from marks on the fly wheel, the former method for setting valves has been almost universally adopted.

As soon as the engine is finished, two marks, diametrically opposite, are located on the rim of the fly wheel, such that when one is directly over the center of the main shaft, the piston will be at one end of its stroke, or in other words, when either of these marks is on top, the piston will be on one of its "dead centers."

Referring to Fig. 17 you will note that when the mark "H" passes a vertical line drawn through the center of the shaft, the piston has just reached the outer end of its stroke, and when the mark "C" comes into this position then the opposite condition is true. These points, as mentioned before, are respectively the head and crank end "dead centers."

Experiments have shown that the exhaust valve should open about 35 or 40 degrees before the crank arrives at the "crank end dead center." Therefore, No. 3 shows, approximately, relative positions of crank and piston when this opening should occur. In order to mark this position a line is drawn across the fly wheel at the point "E." Next, as the closing should take place from 5 to 10 degrees late, that is after passing the "head end dead center," the point "O" is located as represented in this position. The inlet, of course, opens immediately after the exhaust closes, so that the point "P" is next marked off a short distance back of "O." Lastly, the time of closing the inlet is determined (this varies from 20 to 50 degrees after crank has passed the "crank end dead center") and the point "I" settled upon.

Having located correctly all points of opening and

closing of valves, we are ready to proceed with the timing. Glancing at Fig. 18 you will notice that No. 1 shows the cam just about to raise the plunger which

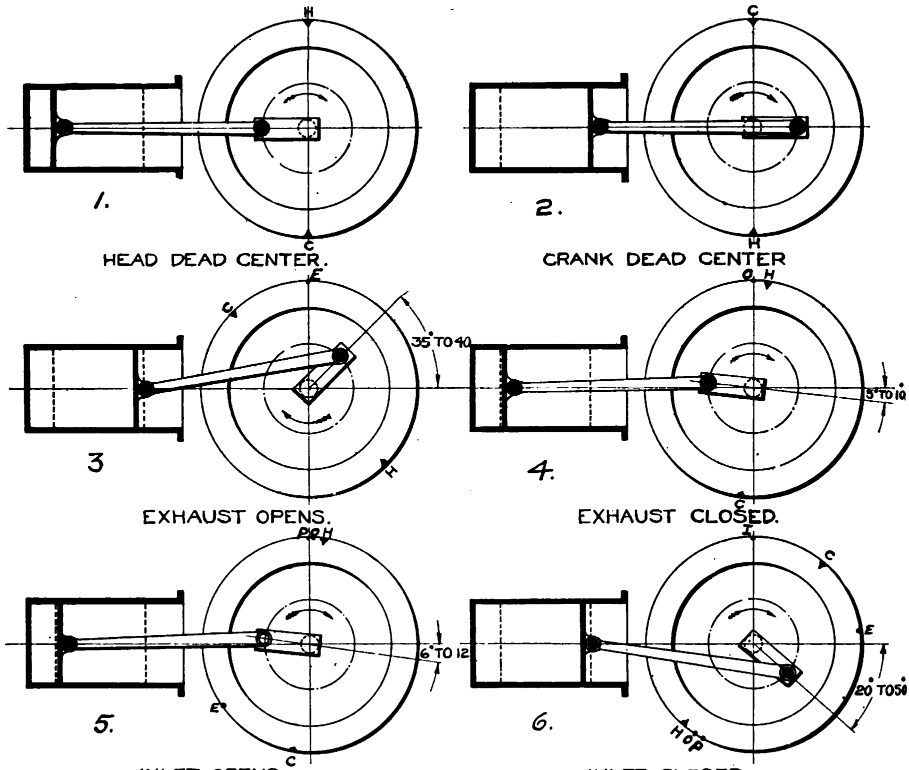


FIGURE 17—VALVE TIMING DIAGRAM.

operates the valve, No. 2 shows the valve at its highest point, or maximum lift, and No. 3 the position of the cam and roller at the point of closing. You will notice that a small amount of clearance is left in order to insure a proper seating of the valve when the cam has

left the roller. It will easily be seen that as soon as the cam has turned far enough to cause friction between itself and the roller, the plunger will begin lifting the valve. As long as the roller turns freely it may be assumed that the valve is resting on its seat, but as soon as it appears to turn hard it is taken for granted that the valve is beginning to open. Naturally, when the cam is leaving the roller, the reverse is true.

Now let us return to our original proposition, and

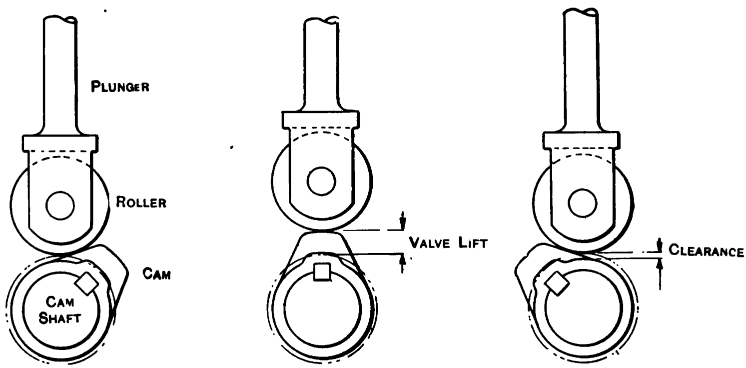


FIGURE 18.

see what use can be made of all this. We will first turn the fly wheel over with the starting crank until the point "E" is directly over the center of the crank shaft. According to our calculations, the exhaust valve should be on the point of opening. Place your hand on the roller at the bottom of the valve plunger, and see whether or not it turns freely. If you find that it moves easily, turn the engine a little further in the direction of the arrow. A slight movement should cause the roller to tighten; if it does not, it shows that the cam has not yet come in contact with it, and hence

the valve will not open soon enough. In this case turn the wheel back to its former position, and move the cam back around the cam shaft until the valve begins to open at the proper time. Frequently, in doing this, however, you will find that it will be impossible to make the valve close properly, and in that case it is

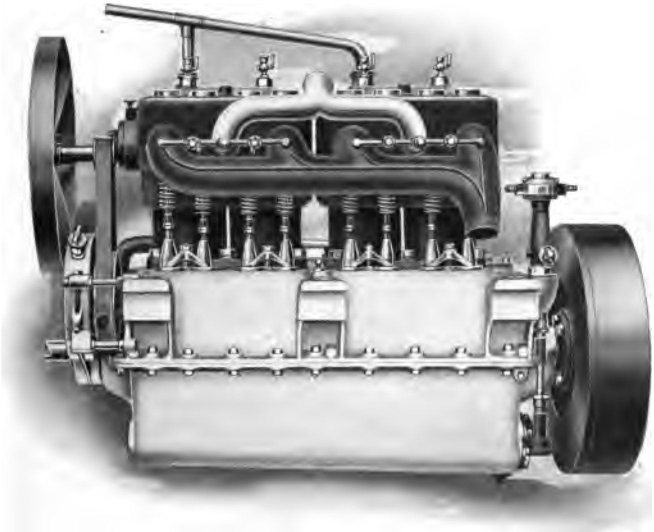


FIGURE 19.
THE VALVE SIDE OF A FOUR CYLINDER FOUR-STROKE CYCLE MOTOR.

necessary to braze a small piece on the side of the cam to increase its width in order to hold the valve open its required time. Having adjusted the opening, turn the fly wheel around until the mark "O" shows up on top, and proceed in a smiliar way to find whether or not the roller frees itself at the right moment.

Assuming that the exhaust valve has been satisfactorily timed, let us direct our attention to the inlet.

Turn the fly wheel over as before until the point "P" is just over the shaft. Then try the roller to see if it is just beginning to stick. If this is true, we can go on; if not, the same method of procedure has to be followed as in the case of the exhaust valve. When the time for opening has been adjusted correctly, revolve the wheel until the mark "I" comes into position, when, of course, the roller should begin to loosen. After a little practice, by simply changing the shape of the cam either by filing off or adding to its surface, you will be able to secure the results desired.

Each engine requires a slightly different valve timing, so it is impossible to give definite data regarding the above. Each manufacturer furnishes an instruction book which gives detailed information regarding proper valve timing to be used for any particular size of motor. Diagram No. 17 may be made of considerable assistance by properly substituting the values of angles given in the instruction book.

VALVE GRINDING. Coupled with the knowledge of valve timing there should be a good understanding of the method of valve grinding. No matter how carefully the valves may be timed, the engine will still lack power if the valves are leaky and not properly seated. You have all, no doubt, noticed how glass stoppers are ground into bottles in order to secure water-tight joint. The grinding of valves is done in practically the same manner, and for virtually the same object. Having first considered the end to be obtained, let us see how it is accomplished: First, above all things, stuff a large piece of waste, tied to a string, into the chamber leading into the cylinder, thus making sure that no abrasive substances, such as emery, can enter

the combustion space proper. This precaution is necessary because it sometimes happens that the emery used in grinding works its way in between the piston and cylinder walls, and badly scars the surface of the cylinder and rings.

Next take off the spring and attachments, and lift the valve out of its seat. Examine both the surface of the valve and its seat carefully, noting any defects or

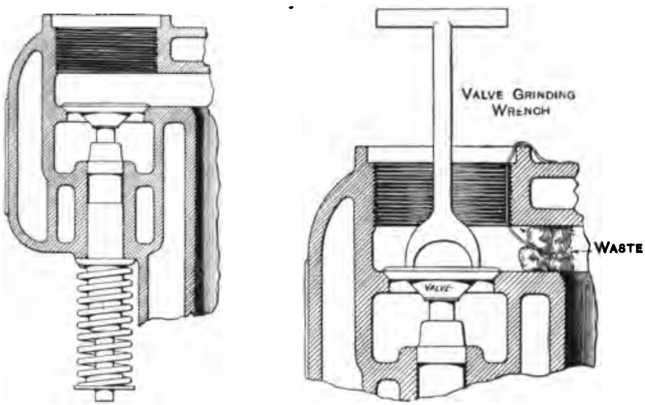


FIGURE 20 GRINDING A VALVE.

peculiarities. Then coat the seat with a mixture of emery flour and oil, and place the valve back in its former position. Insert the wrench as shown in Fig. 20, and grind the valve into place, being careful to examine both surfaces now and then to insure that there is no foreign substance present which could wear grooves in the seat. It is only necessary to press down very slightly on the valve when grinding, the best results being obtained by simply twirling the valve around, and lifting it once in a while to prevent wearing in one place. The grinding should be kept up until both sur-

faces are in contact at every point, and the joint absolutely tight. A good way to tell when this has been accomplished is to remove the valve and wipe the surfaces clean, then apply a coating of Prussian blue. Upon replacing the valve and turning a few times all points not in contact will still remain blue, while the remaining portions will show up bright. As soon as the whole surface becomes bright the valve may be

FIGURE 21—A PISTON, PISTON RING AND PISTON PIN.

withdrawn, and the emery and oil washed out with kerosene. After a little practice one becomes very expert at it, and will soon be able to "grind in" a valve in a very short time.

THE PISTON. You recall that in one of the former sections, we compared the piston of a gas engine to the bullet in a gun. The piston is essentially a projectile with its distance of travel limited to the stroke of the engine. Thus you can see that the first quality which it must have is that it may traverse the cylinder

without an undue amount of friction, and yet at the same time fit the cylinder so perfectly as to allow practically none of the explosive gas to leak past into the crank case. This condition is practically impossible to attain with the piston alone, and consequently, gas engine designers found it necessary to equip the piston with flexible rings in order to meet this contingency.

The piston itself is made of cast iron, for several reasons: Notably, first, because cast iron is very strong under compression; secondly, because it is

FIGURE 22—THREE TYPES OF PISTONS.

easily worked; and third, because it has good bearing qualities. These characteristics more than compensate for the slight additional weight as compared with steel. It is necessary for the piston to possess both strength and durability, for the reason that it not only acts as a piston, but also as a guide or "cross-head" as well.

Another point which must be taken into consideration in the design is the fact that the metal is subjected to an unequal expansion, the closed end next to the burning gas expanding more than the open end. Therefore, all pistons are tapered slightly, so that when this expansion takes place, the piston will assume a true cylindrical form. In addition to this, the central

portion of the piston is turned to a smaller diameter, both to aid the lubrication and reduce the bearing surface, so that the friction on the side of the cylinder wall will not be excessive.

Figure 23 shows two views of a typical form of piston, No. 1 being a complete piston, and No. 2, a section showing arrangement of bosses and webs inside.

No. 1. No. 2.

FIGURE 23.

PISTON PINS. The piston pin is placed nearly in the center of the piston, in order to insure that the pressure transmitted by the connecting rod will be distributed uniformly on the bearing surface. It is a solid or hollow steel shaft, running directly across the piston and firmly fixed at both ends. There are various methods of fastening the piston pin, a few of the most common being shown in Figure 24. No. 1 shows a pin of varying diameters, which is forced in from one

side and held in place by a small ring sprung into a groove. No. 2 shows how the same result is obtained by the use of set screws. No. 3 illustrates the use of expanding plugs, and No. 4 an arrangement using a ring similar to the regular piston rings, whereby the pin is kept from sliding out of place.

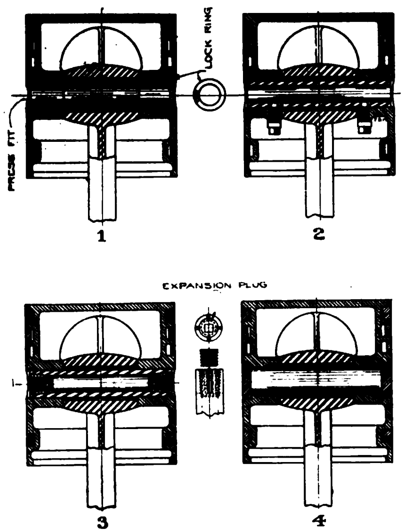


FIGURE 24—METHODS OF FASTENING PISTON PINS.

PISTON RINGS. The piston rings are used, as mentioned above, for the purpose of securing a perfectly fitting moving joint. They are made of cast iron, turned eccentrically and sawed in two at the thinnest point. To insure an accurate fit, the rings are turned to a slightly larger diameter and then cut, so that when the ring is pressed together, its diameter will just equal that of the inside of the cylinder. Piston rings are not cast separately, but one large casting is made,

from which several rings may be cut. This casting is placed in a lathe and turned down inside and outside to a slightly larger thickness than the thickest portion of the finished ring. The casting is then cut up into rings of the proper width. Another man then takes them in hand, and after sawing them in two in some such way as indicated in Fig. 25, places them in a jig, where they are turned eccentrically. As these rings are usually made in large quantities, they are generally

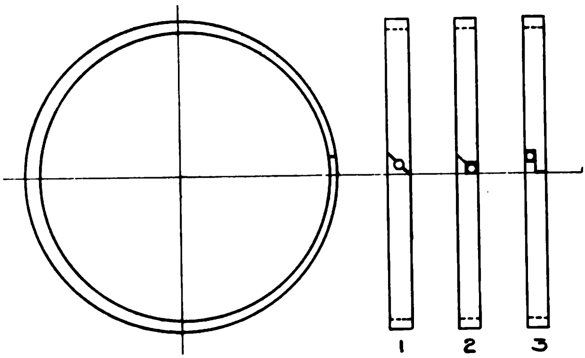


FIGURE 25—METHODS OF CUTTING PISTON RINGS.

left slightly larger than necessary, and later ground to fit the particular cylinder for which they are to be used. The operation of fitting rings is a very delicate one, and requires some skill to properly accomplish it. In order to insure that the rings shall be of the right width, they are placed upon the table of a piston ring grinder and carefully ground off to the desired size. When the rings have finally been finished in this manner, they are ready to be fitted over the piston, which has meanwhile been ground to fit the cylinder.

The location and forms of rings varies with the judg-

ment of the designer, three rings at one end being deemed sufficient by some, others using four rings, three at the closed end and one at the open end of the piston. Still others satisfy themselves with three rings and two or three oil grooves.

CONNECTING ROD. The connecting rod, as the name indicates, is simply a connecting link between the piston and the crank shaft. It is made of drop forged steel or brass, and is of "I beam" section. The

FIGURE 26—A TYPICAL CONNECTING ROD.

length depends upon the space available, but should never be shorter than twice the length of the stroke. The longer the rod, the less side pressure will be produced on the cylinder wall, and consequently less wear and tear on the bearings. The piston end is generally fitted with a bronze bushing which is adjustable for wear, while the crank end bearing is either bronze or babbitt. Bronze bushings are harder to bore and require considerably more work to finish, and for that reason babbitt is more often used. In addition to this, any grit which might work its way between the crank and bearings would be buried in the babbitt before it had a chance to cut the shaft. Sometimes, as a com-

promise a combination babbitt-bronze bearing is made, in which a certain portion of the bronze is cut out and filled with babbitt, thereby combining the desirable features of both. Fig. 27 shows the various forms of connecting rods used in modern construction.

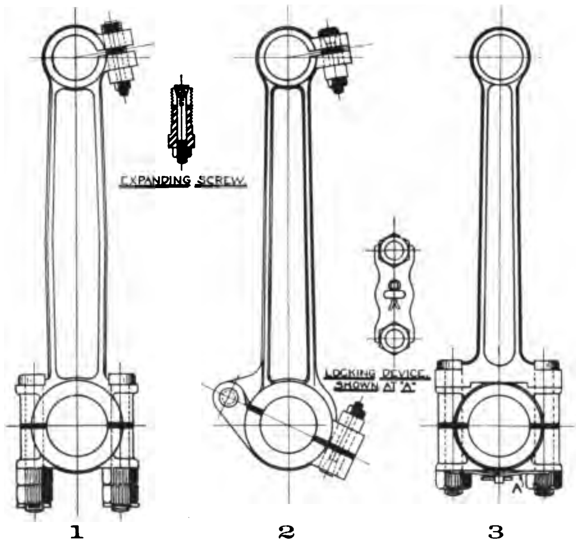


FIGURE 27—MODERN FORMS OF CONNECTING RODS.

LUBRICATION OF PISTON AND CONNECTING ROD. The devices used for lubricating the connecting rod bearings are many and varied. The most common method used is that known as the "splash" system. The crank case is kept partially filled with oil, and the constant churning of this by the crank and counterweights produces an oily mist which very nicely lubricates both bearings. Other systems are employed, whereby oil or grease is forced through a hollow crank shaft and out into the bearings.

In a horizontal cylinder, such as that shown in Figure 12, you will note that an oil tube is screwed into the cylinder wall directly above a hole in the piston. The oil running down this pipe drops through the opening in the barrel of the piston and falls upon the wrist pin. Besides taking care of this bearing, it also helps replenish the supply in the crank case. The piston picks up enough oil to lubricate itself, being aided, of course, by the cuts in the rings, which help distribute the lubricant along the surface.

FIGURE 28.
THE CRANK SHAFT BEARING OF A CONNECTING ROD SHOWING OIL GROOVES AND OIL SLOTS.

THE CRANK CASE. The crank case of the motor generally serves four purposes. First, it acts as a foundation for the engine. You will notice in Fig. 31 that webs are cast on the sides of the case, and so shaped that they may be bolted to the frame. This type of construction is used for multiple cylinder motors, and all crank cases are built in very much the same way, differing only in slight details. In horizontal motors, however, we use a different form of construction, supporting the engine not only by means of the crank case, but by the cylinder as well. In the

case of the single cylinder horizontal motor, shown in Fig. 29, you will notice that the arrangement is such that one cross brace of the frame passes under the end of the crank case, while another is bolted to the under part of the cylinder. The method of supporting the two-cylinder opposed type is very much the same except that in general the crank case alone is bolted

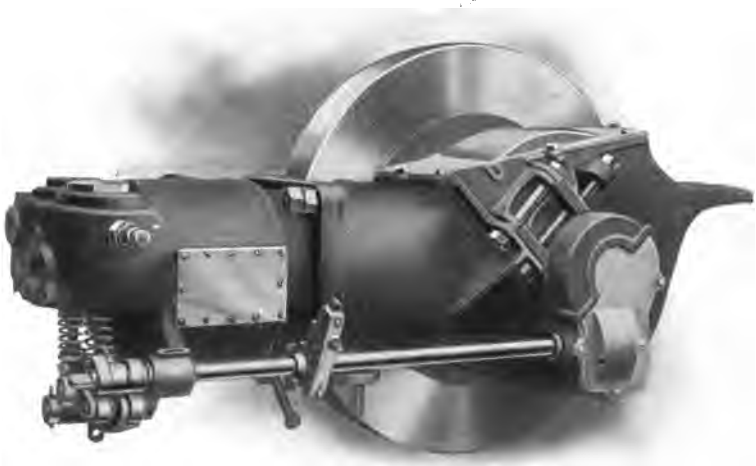


FIGURE 29.
A SINGLE CYLINDER MOTOR, SHOWING CRANK CASE CONSTRUCTION.

down. In many cases a tubular form of construction is used whereby the motor is supported by means of steel tubes running through the sides of the crank case.

Second: The crank case also supports the main bearings, large bosses being provided at each point where bearing is desired. You will note by referring to the figures that these are strengthened by means of webs running out from the crank case walls. Very

often the castings are "cored out" so that cavities are formed in the upper part of these bosses in such a position that oil thrown up by the crank is allowed to drain down into the bearings, thus giving a very good and easy method of lubrication.

A very novel lubrication system is shown in the illustration. Absolutely no piping is used, the oil traveling through grooves cut into the casting itself. The lower

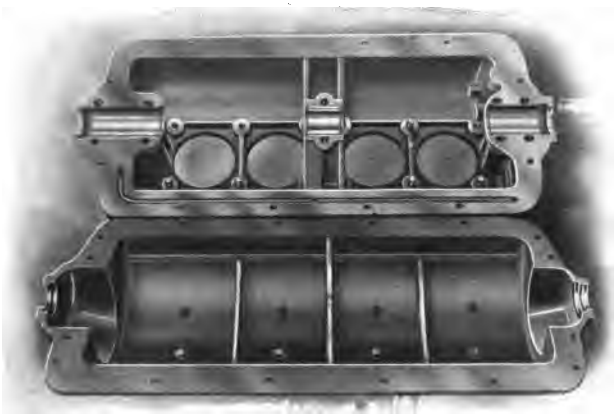


FIGURE 30—A FOUR CYLINDER CRANK CASE.

part of the crank case is provided with an oil reservoir from which the oil is pumped to all the bearings by means of a gear pump. Each of the crank shaft bearings is connected by means of a hole drilled through the casting with the canal, which, you notice, runs along the side of the upper half of the crank case. An excess of oil is furnished, but in no case is it wasted, as it is allowed to drain back into the "oil pan," from which it is again pumped through the system.

Third: The crank case furnishes an air tight com-

partment in which the crank may revolve, thereby insuring that no dust or abrasive substance can reach the crank pin and wrist pin bearings. When the "splash system" of lubrication is used, the crank case

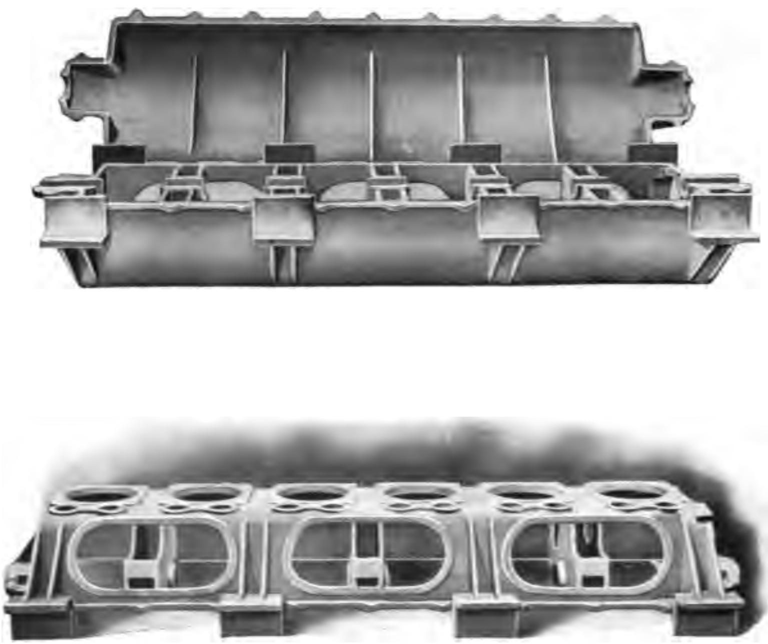


FIGURE 31—TWO VIEWS OF A SIX CYLINDER CRANK CASE.

furnishes a receptacle for the oil. In order to prevent the oil from flowing down to one end when the machine is on a grade, thus starving some of the bearings, small webs are raised in the lower half, or "oil pan," as it is called, thereby always allowing a certain amount of oil to be retained under each cylinder.

Fourth: The pressure created in an air-tight crank

case is many times utilized for forcing gasoline into the carburetor, or oil through a lubricating system.

THE TWO-STROKE CYCLE CRANK CASE. In addition to these uses, the crank case of the two-stroke cycle motor is used as a compression chamber, and therefore differs slightly in form from that of the four-stroke cycle motor. It is made air-tight, and its volume is so figured that it will be as small as possible

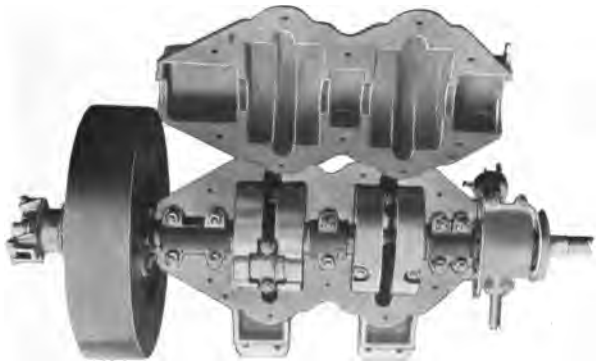


FIGURE 32—TWO-STROKE CYCLE MOTOR CRANK CASE.

and yet have walls clear the connecting rod. Often this volume is decreased by inserting blocks of wood or aluminum or cast-iron crank discs. In many of the smaller motors two small fly-wheels are keyed to the shaft inside the crank case chamber, the object being, of course, to reduce the crank case volume, thereby obtaining a large initial compression pressure. During the last year or two many of the automobile manufacturers have been experimenting with two-stroke cycle motors, and have produced crank cases of relatively very small volume.

THE CRANK SHAFT. The main shaft, or crank shaft, as it is commonly called, is perhaps the most important part of the engine, for the reason that it is the part which changes the reciprocating motion of the piston to the rotary motion of the fly wheel. It must be built strong enough to withstand forces in both of these directions, and consequently its design is a matter for careful consideration. While it is very easy to design a crank shaft large enough to transmit a given power, yet at the same time every increase in diameter means an increase in the size of bearing, size of crank case, and hence size of engine. Therefore, in order to keep down the weight per brake horse power developed, engineers are careful to figure sizes very closely. Special steels are used which will stand greater stresses, thus enabling the crank shaft to be made smaller. Where crank shafts are made in great numbers, drop forged shafts are made, which are afterwards turned down to size. After these are within a few thousandths of an inch of the required diameter, they are carefully ground to fit the bearings for which they are intended.

Formerly all crank shafts had to be forged out by hand, or cut out of a solid block of steel. This, of course, meant several days of work, and in the end it is doubtful whether they were very much better than a good drop forged shaft of today. When extreme hardness is desired, crank shafts are case hardened, that is, they are imbedded in some carbonaceous substance, such as bone dust, and allowed to bake until a portion of this carbon has entered the surface of the steel. The great difficulty in this sort of treatment is that the

FIGURE 33—SINGLE-CYLINDER CRANK SHAFT.

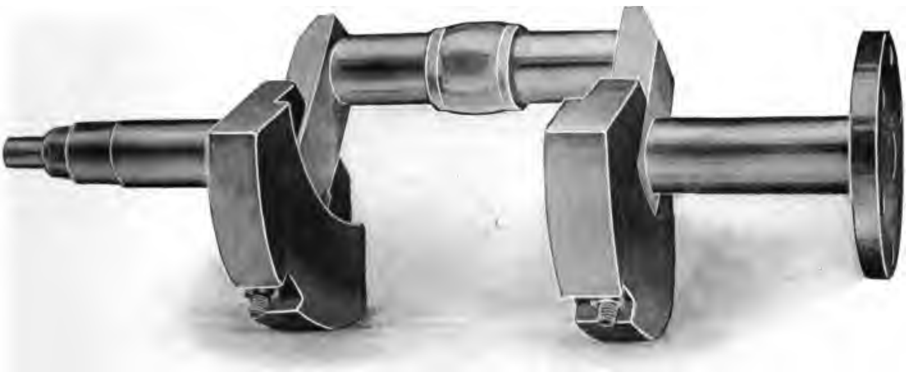


FIGURE 34—TWO-CYLINDER CRANK SHAFT, CRANK ON SAME THROW.

FIGURE 35—TWO-CYLINDER CRANK SHAFT, CRANK AT 180°.

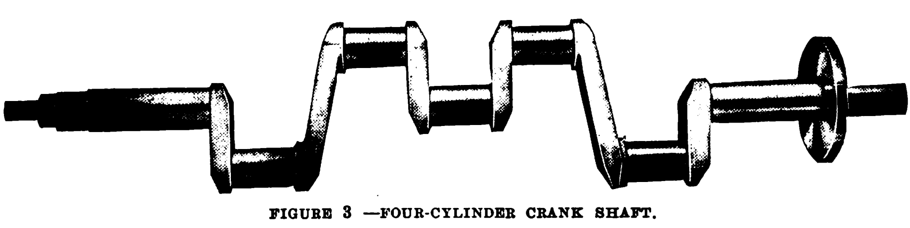


FIGURE 3 —FOUR-CYLINDER CRANK SHAFT.

heat is very apt to warp the shaft, and great care has to be taken in order to prevent this. There are several special treatments which are used, many of which give very excellent results.

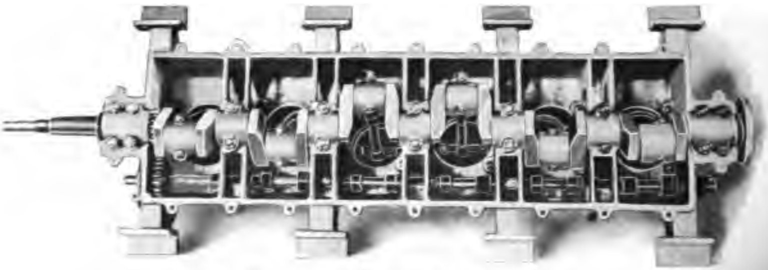


FIGURE 37—SIX-CYLINDER CRANK SHAFT.

Regarding the form of the shaft, crank arms, and crank pin, a glance at the photographs will indicate the types used in modern practice.

RELATIVE CRANK POSITIONS—SINGLE CYLINDE[R] CRANK SHAFTS. In order to explain the various [...]tings of cranks in multiple cylinders and motor[s] [...] writer has drawn the diagrams shown in Fig. 39[...] will note that, first each cylinder, piston, co[...] rod, and crank shaft is shown diagram[...] Next, the relative positions of the cranks a[...] in the small circle to the right. Then, in [...] the relation of the working strokes, [...] drawn, one revolution of which rep[...] cycle of a four-stroke engine. I[...] quarter of the diagram is suppo[...] stroke of the motor. Therefo[...] start with a working stroke r[...]

portion, you will notice that this stroke ends at the first quarter mark. Then the exhaust stroke occurs during the remaining half, the suction stroke begins at that point, and continues until the three-quarter mark is reached. Similarly, the exhaust is represented

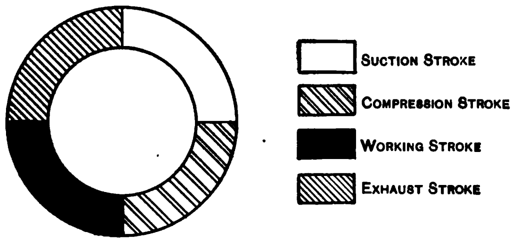


Fig. 38.

by the fourth quarter. Thus the conditions in the single cylinder engine are very easily pictured.

TWO-CYLINDER CRANK SHAFTS. Passing now from the single cylinder, let us take up the type of motor where two cylinders, set side by side, or twin cylinders, as they are usually termed, are used. If we start at the working stroke in cylinder No. 1, and assume that the cranks are set on the same throw, the inside circle will represent the sequence of conditions in this cylinder. Likewise, the outside circle will indicate how the same conditions occur in cylinder No. 2, and resulting diagram shows very plainly that the working stroke in cylinder No. 1 comes in a different revolution from cylinder No. 2, or, in other words, the explosions are balanced. This type of motor, however, requires counter-weights on the crank shaft in order to balance the crank pins, connecting rods, and pistons.

With this in mind, let us take up the next type, where the cranks, instead of being set together, are 180 degrees apart. Here you have slightly different conditions. You will notice that instead of the explosion coming in different revolutions they here fall in the same. Therefore, during one revolution the engine receives no impulse. On the other hand, the cranks are balanced, or nearly so, at least, as far as the turning effect is concerned. However, there is a bending moment produced which tends to rock the engine. This is partially overcome in some motors by the introduction of two counter-weights, one opposite the extreme right crank arm, the other opposite the extreme left.

The two-cylinder engine which combines balanced parts and balanced explosions is known as the double opposed. The cranks are set at 180 degrees, and you will notice in the diagram that as both pistons go down at the same time, alternate explosions follow each other at one revolution intervals.

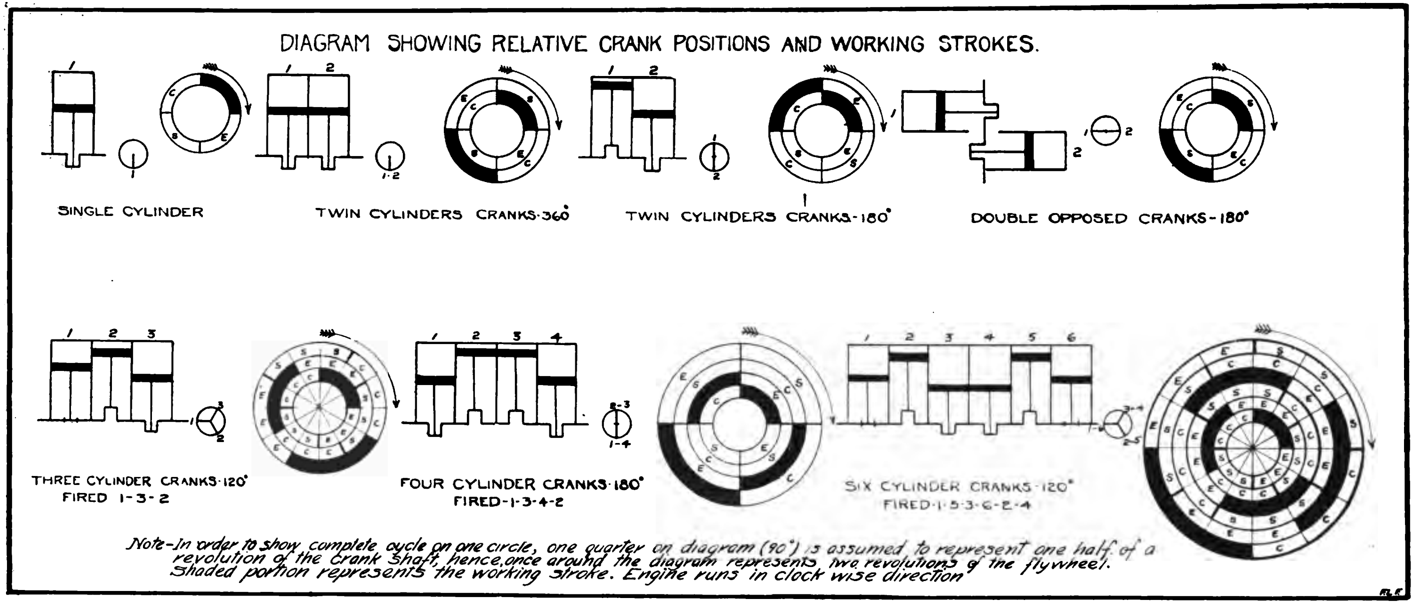


Fig. 39.

In all of these diagrams, the inside circle represents cylinder No. 1, the next one outside cylinder No. 2, and so on. The letters, S, C and E mean respectively suction, compression and exhaust; the working stroke being represented by the shaded portion. Another interesting feature of these diagrams is the fact that they show the proper method of firing each motor. The great aid in working any problem of this sort is to make a model of the engine out of cardboard, and mark positions of pistons and crank pins.

THREE AND SIX-CYLINDER CRANK SHAFTS. Up to this point, these diagrams have undoubtedly been clear, but for the three-cylinder and six-cylinder motors, the problem becomes slightly harder. It is necessary to divide the diagram now into twelve parts instead of four, as the cranks are set at 120 degrees instead of together, or at 180 degrees. However, the same general principle applies, and if you will carefully study the diagram, the operations will undoubtedly be made clear.

THE CARBURETOR

CARBURETION. Many of the uninitiated think that a carburetor is a very complicated piece of apparatus. Yet if they were to study the principles of carburetion they would be surprised at the simplicity of this most necessary part of the gas engine.

A carburetor is a device for producing a mixture of fuel and air in a correct proportion for complete combustion.

You have, no doubt, seen the physician give an anesthetic, yet it has doubtless never occurred to you that in this operation he makes use of the same principle as that employed in the gas engine carburetor; whether he uses a handkerchief or a cone, the same result is obtained, namely, that of producing a vapor of chloroform and air. The handkerchief becomes a carburetor in a wide sense of the word. When it is saturated with the anesthetic, and the air drawn through, particles of vapor mix with the air, and enter the mouth and nostrils as a mechanical mixture. You can see that by this method a large amount of vapor is wasted, the air

not being limited to a definite path. If it were limited to a definite path the patient would succumb much more readily, due to the fact that a greater amount of vapor would be received with each breath.

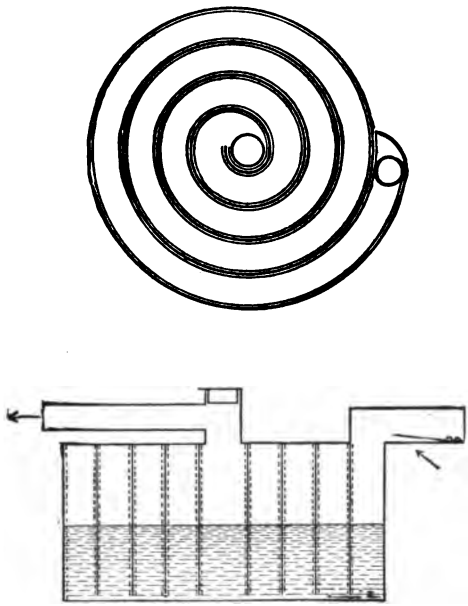


FIGURE 40—A WICK CARBURETOR.

Air enters at right side and passes around to the center of the carburetor. The walls are covered with wicking saturated with gasoline. By coming in contact with this the air becomes saturated with vapor which is carried along into the engine.

With this brief explanation of carburetion, let us see what happens when the same process is applied to the gas engine. The object to be obtained is the production of an explosive mixture, and experimenters have found that a mixture in proportion by weight of 16 lbs. of air to 1 lb. of gasoline will give the best results.

You can easily remember this ratio if you will simply note that 1 lb. of air requires 1 oz. of gasoline.

COMBUSTION. In order to understand why it is necessary to have this proportion of gasoline and air we must consider the subject of combustion. Combustion, or burning as we ordinarily call it, is the rapid

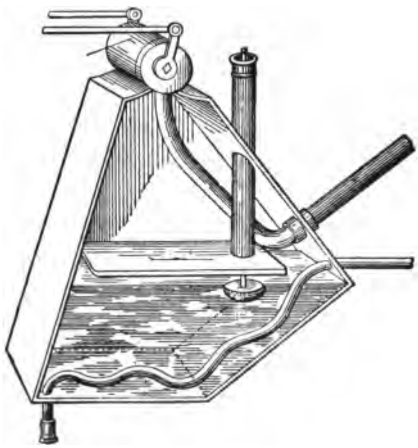


FIGURE 41—DE DION SURFACE CARBURETOR.

Air is drawn down through the vertical tube and allowed to bubble up through the gasoline. The vapor is collected in the upper chamber and finally led out into the engine through the pipe on the right side of the drawing.

union of any substance with oxygen and is accompanied by the development of heat and light.

In order to see the effect of perfect and imperfect combustion, take an ordinary Bunsen burner, and close the air holes at the bottom of the jet. The flame immediately takes on a yellowish hue, caused by incandescent particles of carbon. Then when you open the air holes again, you will note that immediately the flame turns blue and almost colorless, the excess of unburned

carbon which was present in the other case now being completely burned. Thus you can demonstrate that when there is sufficient oxygen present to unite with all the combustible material, there will be no residue left to produce smoke or soot. Therefore, gas engineers have been putting forth their best effort to provide the exact amount of oxygen required to burn a certain amount of gasoline.

GASOLINE. Gasoline is a hydro-carbon distilled from crude petroleum. It is lighter than water, its specific gravity ranging from .73 to .64. It is composed of carbon and hydrogen. During its combustion the carbon must be united with oxygen to form carbon dioxide, and the hydrogen with oxygen to form water. By working out the chemical equations you will find that the proper amount of oxygen necessary to burn 1 lb. of gasoline will be 3.53 lbs. The amount of air necessary to furnish this amount of oxygen figures out 15.3 lbs. This, you see, is nearly 16, and for all practical purposes the ratio 16 to 1 will answer the purpose.

TYPES OF CARBURETORS. There are three ways of mixing the fuel with air. First, by allowing the air to circulate through chambers lined with wicking or some other substance which exposes a large amount of surface to the air. The lower part of the vessel is filled with gasoline, and the wicks are allowed to hang down into this reservoir; therefore, you can see that as the air circulates through these spaces it will take up a certain amount of gasoline in the form of vapor. This method never gave very good results, the mixture would vary, and there was always a residue of gasoline left which, of course, meant loss in fuel economy. See Fig. 40.

The second process is by allowing the air to enter a chamber beneath the surface of the gasoline. The bubbles of air rising through the liquid will, of course, take up a certain amount of the hydro-carbon, and a fairly good mixture will be obtained in the space above the gasoline. This method is open to the same objections as the former, and therefore has been discarded.

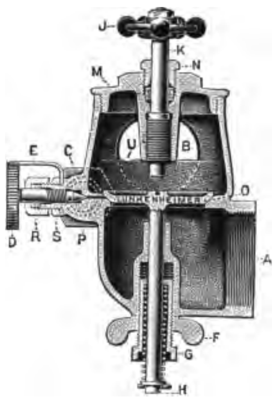


FIGURE 42—A MIXING VALVE.

The third type of carburetor, the one after which nearly all the modern carburetors are patterned, makes use of a system whereby the gasoline is sprayed into the path of the incoming air. There are innumerable ways of arriving at the same result, and every day sees new improvements in methods of controlling the gasoline, and ways of introducing air. Nevertheless, the ultimate object is the same, namely, that of producing a perfectly explosive mixture.

THE MIXING VALVE. The mixing valve is probably the simplest form of carburetor. It has been used

for marine work with very good success, and promises to hold its own for several years to come.

Fig. 42 shows an exterior and sectional view of a very well known generator valve. You will note that it consists of an inlet pipe, the amount of air flowing through being limited by a valve O. At the left you will notice a gasoline feed pipe, provided with a needle valve D by means of which the amount of gasoline is controlled. The operation of this form of valve when applied to the two-stroke cycle motor is dependent upon the alternate periods of pressure and partial vacuum existing in the crank case at the different periods of the cycle. When the engine begins to draw in a new charge, the valve O, normally held on its seat by a spring, begins to open. This action uncovers a small gasoline port in the side of the valve seat, and a given amount of gasoline is allowed to mix with the incoming air. This amount may be very nicely gauged by adjusting the needle valve D. A small hand wheel at the end of the valve stem is provided with numbers which show the different degrees of opening, and it is a very easy matter to properly manipulate the valve. Hence, having found the correct mixture, the wheel may be turned to that point, and left. The lift of the valve may be regulated by means of the small wheel J.

Another form of mixer which has given very good results is the one shown in Fig. 44. The gasoline is forced by means of the diaphragm pump, actuated by crank case pressure, from the gasoline tank up through a system of piping, and down into a gauze cone placed in the center of the inlet pipe. The air entering strikes this small body of gasoline retained by the gauze, and immediately breaks it up into a spray and carries it

on into the engine. The amount of air admitted is controlled by means of a gate placed in the inlet pipe.

The flow of gasoline may be adjusted by means of a needle valve in the gasoline pipe.

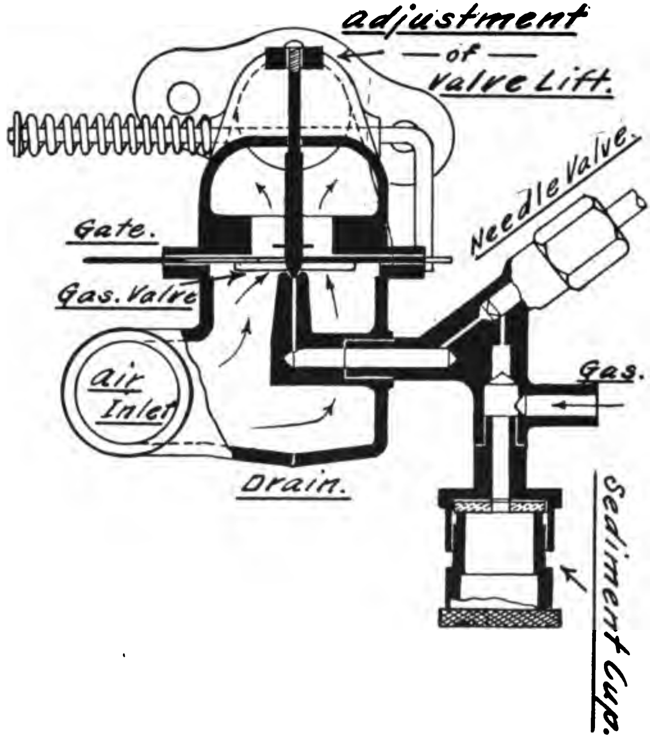
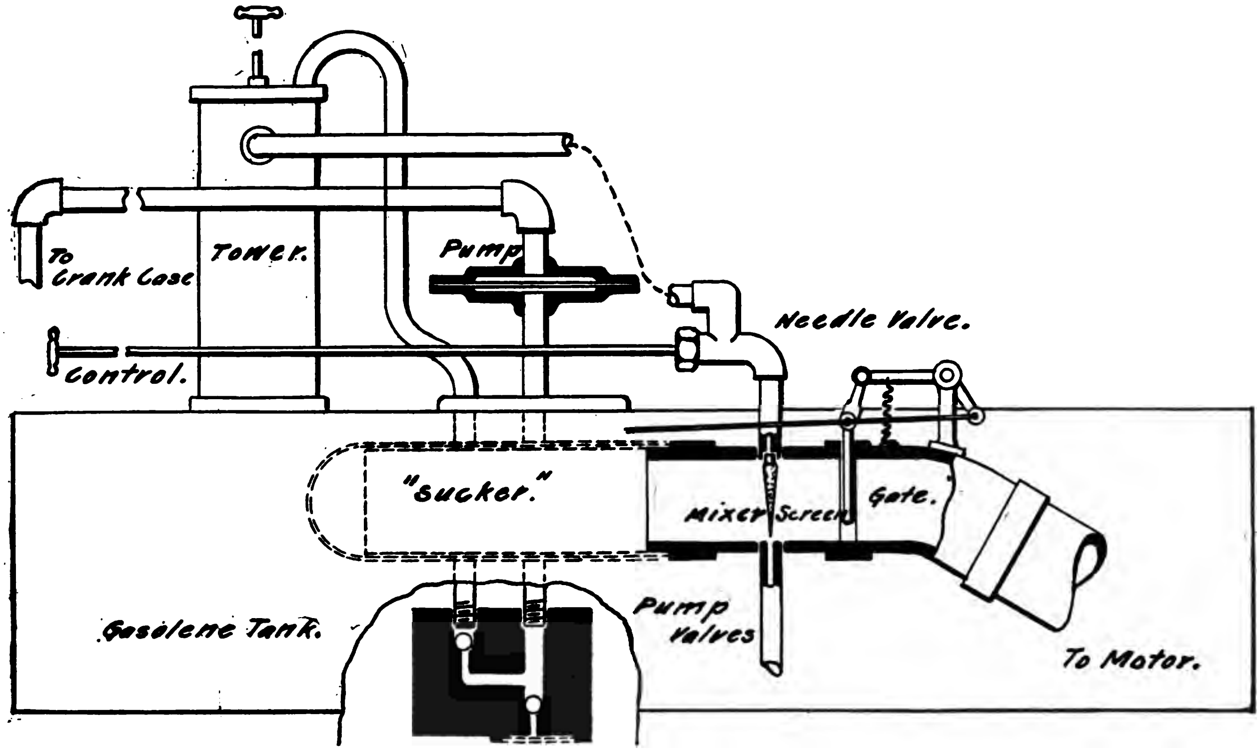


FIGURE 43.

Another type of mixing valve is that shown in Fig. 43. The system here used is nearly the same as that of the generator valve, with the exception that a small needle valve is used in the place of the disk, and the amount of air is regulated by means of a gate passing over the gasoline nozzle.



Tower.
To
Crank Case
Pump
Control.
Needle Valve.
"Sucker."
Mixer
Screen
Gate.
Gasolene Tank.
Pump
Valves
To Motor.

FIGURE 44.

The principal trouble to which carburetors of the mixing valve type are subject is caused by there being no device for maintaining a constant pressure or "head" at the outlet of the gasoline nozzle. You can readily see that when the gasoline tank is full the pressure will be greater than when it is nearly empty, due, of course, to there being a greater volume of gasoline

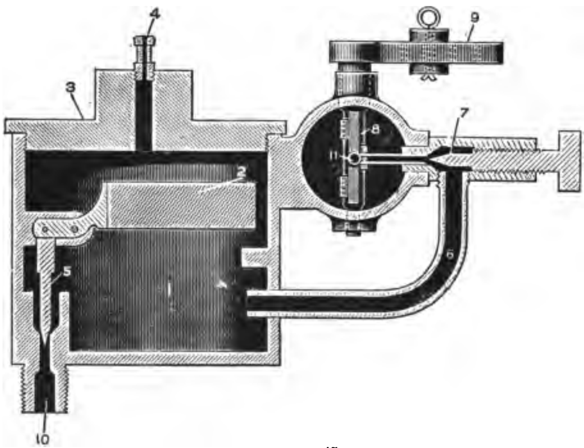


FIGURE 45.

above. As the tank is emptied, the level gradually drops, and the pressure at the nozzle decreases accordingly. Thus, you can see, that when the machine is driven up a very steep grade, and the gasoline rushes to one end of the tank, the carburetor may be either flooded or starved, depending upon the position of the gasoline outlet. The same effect is sometimes caused by driving a car rapidly around a corner. The centrifugal force throws the gasoline to the outside of the tank, and if the gasoline valve happens to be on that

side the carburetor is flooded, sometimes to such an extent as to completely stop the motor.

THE FLOAT CHAMBER. It soon became evident to gasoline engine designers that it would be necessary to equip carburetors with a device which would maintain a constant level under all conditions. In modern carburetors this is accomplished by means of a float chamber. A float chamber is nothing more or less than a small auxiliary gasoline tank in which is placed a float used to control the ingress and egress of the

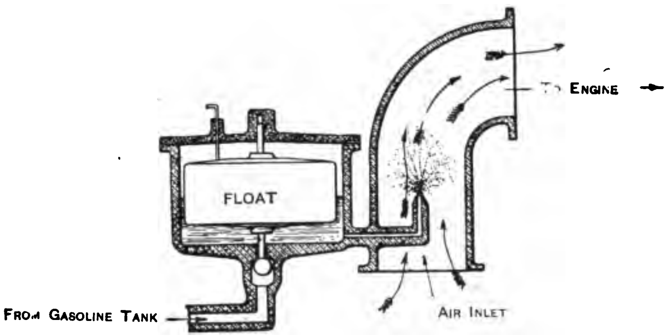


FIGURE 46.

liquid. Float mechanisms are of various types, one of the simplest being shown in Fig. 45. You will note that a small lever, fitted with a cork at one end, and a needle valve at the other, is suspended from the side of the chamber. The weight of the cork upon the valve allows the gasoline to flow up from below until the level is sufficiently high to float the cork. At this point the needle, which has meanwhile remained slightly above its conical seat, is lowered into place, and the flow of gasoline is completely cut off. As the fuel is used, the level again sinks, and the valve is allowed to reopen. Thus, you see. that this simple device very

nicely takes care of the difficulty. Another form of float, more often used, is shown in Fig. 47. Here the

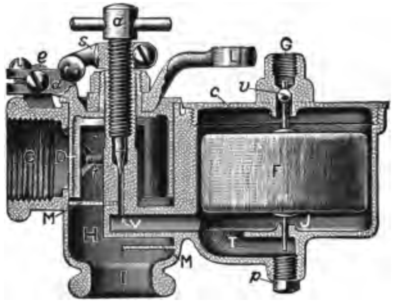


FIGURE 47.

valve consists of a ball which is so arranged that it fits into a conical seat in the cover of the float chamber.

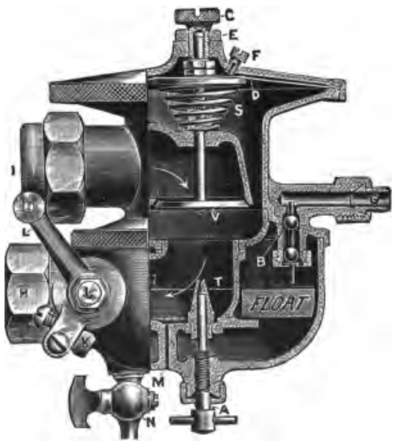


FIGURE 48.

The float itself is mounted upon a spindle, which is kept in a vertical line by means of upper and lower guides.

The method of operation is virtually the same as that described above; that is, the valve remains open until the float rises to a high enough point to cause the valve

FIGURE 49 A.

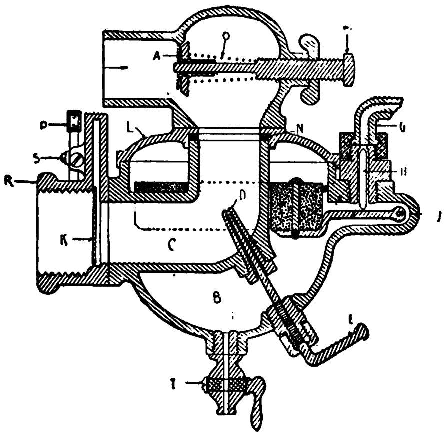


FIGURE 49 B.

to seat. Other types of float chambers are shown in Figs. 48, 49, 50 and 51.

MODERN CARBURETORS. Having thus obtained a

steady flow of gasoline, it was next necessary to make sure that the proper amount of air was introduced to burn the fuel. This led to many forms of mixing chambers, gasoline jets, needle valve adjustments, and auxiliary air valves. In order to understand more clearly

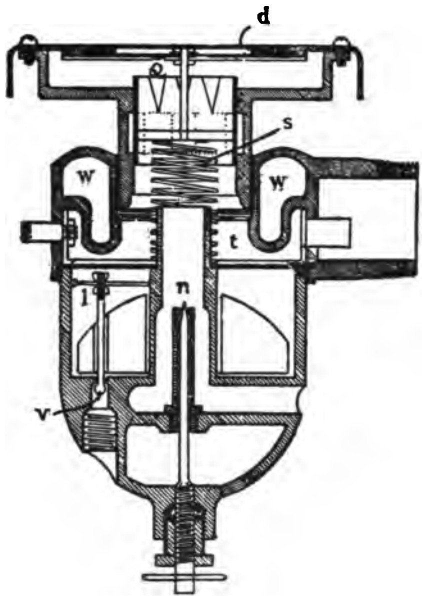


FIGURE 50.

how these changes have come about, we will take up one of the simple types of carburetors shown in Fig. 45. This consists simply of a pipe fitted with a float chamber and gasoline control valve. The air comes in from one end of the pipe, strikes a gasoline jet placed in the center, and the resulting gasoline vapor is carried on into the engine. Two butterfly valves, one at the air end, and one at the engine end of the pipe, control the

flow of the gas. A simple needle valve, "7," controls the flow of gasoline from the float chamber. This is a very simple device, and gives good results, considering the small number of parts used. One of the troubles,

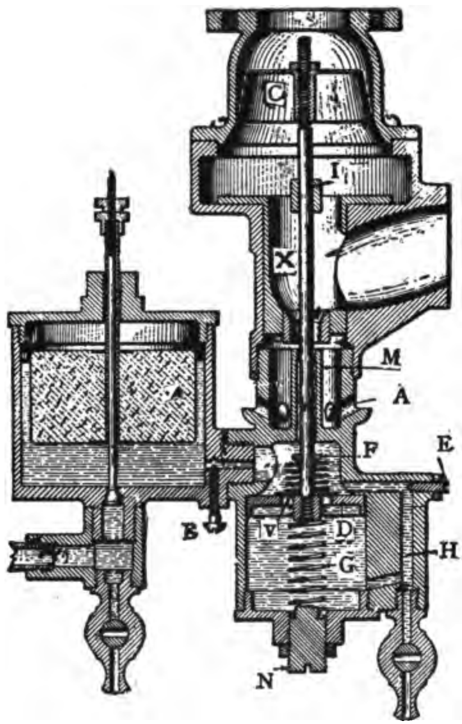


FIGURE 51.

however, with a mixing chamber of this type, is that there is no automatic valve for taking care of the varying speeds of the motor.

Fig. 47 shows another type of carburetor in which the flow of both gasoline and air is controlled by one throttle lever. The rate of flow of gasoline is deter-

mined by screwing and unscrewing the needle valve "A" until the correct mixture is obtained. Of course, very much depends upon the taper of this valve, and therefore it must be very carefully ground to the proper angle, and kept in that condition in order to

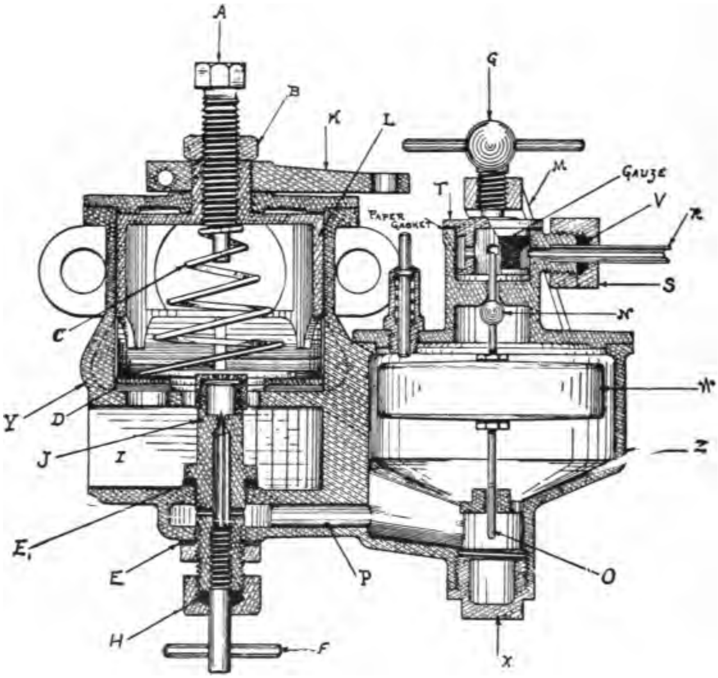


FIGURE 52.

insure a proper mixture at all times. You will note that an opening is cut in the side of the rotating barrel so that when the throttle is closed the relative amount of air is comparatively small. This is necessary for the reason that in starting it is always better to have a rather rich mixture, because gasoline does not vola-

tilize as readily then as it does after the motor has been running for some little time.

The action of the carburetor is very simple, and can be readily seen from the drawing. The gasoline comes in at the top of the float chamber through the pipe "G," past the float valve and into the float chamber. After the engine is started the suction created in the cylinder causes the gasoline to be drawn through the pipe "V" in the direction of the arrow out through a jet "J" into the mixing chamber "H," the air meanwhile being drawn up through the inlet "I." The resulting mixture is then drawn through the pipe "C" into the combustion space of the motor. A lever, "L," controls both the opening of the gasoline and throttle valves. Carburetors of this type, however, did not give uniform mixture at all times, and therefore it was necessary to add what is known as an auxiliary air valve.

The balance of the carburetors shown are all equipped with this device, each, however, having a particular form of its own—but all intended for the same purpose, i. e., to provide a means for producing air so that when the engine attained high speed the proper amount of air could be obtained, and at the same time fulfill another set of conditions, that of giving a rich mixture for starting the motor.

The auxiliary air inlet usually consists of simply a valve opening inward, held in its place by a spring of a certain known tension. The strength of the spring is carefully determined so that at the proper moment, when the motor requires more air in proportion to the amount of gasoline used, the valve will open just enough to allow the required amount of air to enter.

You will see that the time and amount of opening will be controlled by the speed of the engine, that is, by the amount of suction produced by the movement of the piston in the cylinder. Of course, as the engine speeds up, there is a greater piston displacement to be filled per minute, and therefore it is necessary to supply a greater amount of mixture. Upon changing speed suddenly, from say 500 revolutions to 900 or 1,000, the carburetor not having this device will not give a uni-

FIGURE 53.

form mixture immediately, and, in fact, it might require a new adjustment of the gasoline flow in order to supply the right amount of fuel. What the auxiliary air inlet actually does, then, is to automatically control, above a certain point, the amount of air admitted, thereby always maintaining a homogeneous mixture. In order to prevent any chattering of the valve or rapid changes in the air supply, a diaphragm or dash pot is sometimes used in connection with the valve.

Fig. 50 shows a type where the former method is used. Fig. 51 is an example of the latter. In Fig.

50, instead of using a regular valve, a piston valve is introduced which, however, accomplishes the same result in a slightly different way.

In some of the later types of carburetors you will notice that the float chamber surrounds the mixing chamber. This, of course, makes the carburetor more

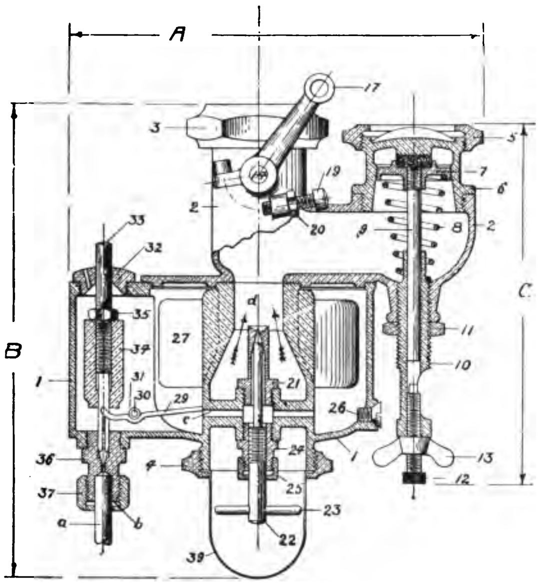


FIGURE 54.

compact, reduces the distance through which the gasoline has to flow, and is in many ways a most satisfactory arrangement.

Improvements are constantly being made along these several lines, and each year brings out something newer and better in carburetor practice.

Fig. 54 shows one of the latest types manufactured by one of the leading companies. It combines many

desirable features, among these being compactness, due to the fact that the float chamber surrounds the mixing chamber, sensitiveness, yet easily controlled by proper system of float levers, improved type of adjustment, auxiliary air valve, practically no corners for gas to turn, easily accessible gasoline adjustment, and a well designed mixing chamber. The operation of this carburetor is as follows: The gasoline enters through the tube (a); this tube is merely slid into the inlet of float chamber, and held in place by packing nut (37), which is screwed tightly in place after being filled with a quantity of packing at (b). As the float chamber fills with gasoline the float (27) rises, thereby allowing the lever (29) to tip on its fulcrum (30) and by so acting allows the gasoline inlet needed to lower to its seat to shut off the inlet of gasoline and maintain the proper level, which is about 1-16 inch below the top of the nozzle (21), the gasoline coming to this nozzle by means of passage (c).

Air enters the mixing chamber (2) through an air passage (d), which is constantly open, and also through the air passage closed by air valve (7). At low speed the air valve (7) remains closed, closing the main air port, while the air passes by the nozzle at considerable velocity on account of narrow passage, accordingly lifting the required amount of gasoline from the nozzle to give proper mixture, and as the speed increases, the increased vacuum opens the auxiliary air valve (7) and maintains a perfectly homogeneous mixture.

One could write page after page describing modern forms of carburetors, but as it is the intention of the writer simply to give some of the principles governing

their construction he will not take the space to go into a detailed description of the various forms. The accompanying cuts will show slight differences in design, yet the same underlying principles will be found in each. Nearly all of the carburetors shown on the following pages are of foreign make, and many have become famous on account of their great adaptability.

FOREIGN CARBURETORS. The Daimler-Phoenix

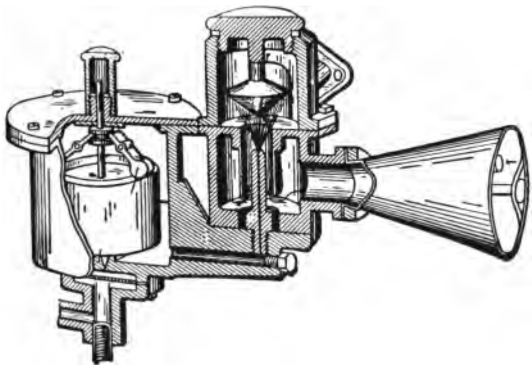


FIGURE 55—DIAMLER-PHOENIX.

carburetor shown in Fig. 55 illustrates a type in which the gasoline is allowed to strike a conical surface just above the gasoline jet. Such an arrangement causes the gasoline to be spread out in a thin mist through which the incoming air must pass, thus insuring more perfect vaporization of the gasoline.

In the Richard-Brazier, two gasoline nozzles are used and are placed in such a position that only a portion of the air passing into the motor will pass the jets. Fresh air comes in at the bottom, as indicated by the arrow, at C, passes the jets GG, the supply of gasoline

being, at these points, controlled by float F, and up through the passage M, where warm air may be added through openings at SS.

The Napier carburetor presents one new feature, that being the horizontal piston actuated by the governor. The gasoline in this carburetor passes through the filter chamber C up into the float chamber G, and

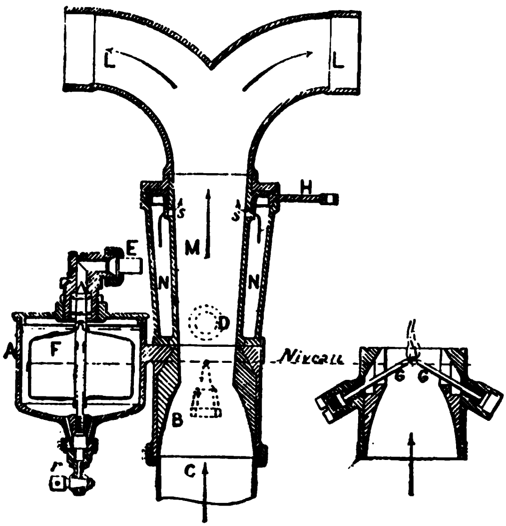


FIGURE 56—RICHARD-BRAZIER.

from it is fed as needed into the mixing chamber of the carburetor. The main air inlet is shown at H 1, the air passing through this opening strikes the gasoline jet at K, and immediately forms a mechanical mixture with the fuel. From here it passes through holes in the piston J 4, and out into the inlet pipe J 2. This piston, J 4, is connected with the governor of the engine, and acts as a throttle for the motor, increasing or decreas-

ing the speed automatically as required, by cutting off or opening the passage leading into the inlet pipe. A hand throttle is also provided, and may be operated by turning the pin H 2.

Another rather interesting type of carburetor, used on the Decauville car, is that shown in Fig. 58. In order to vary the amount of air passing through the mixing chamber, a cone mounted upon a vertical spin-

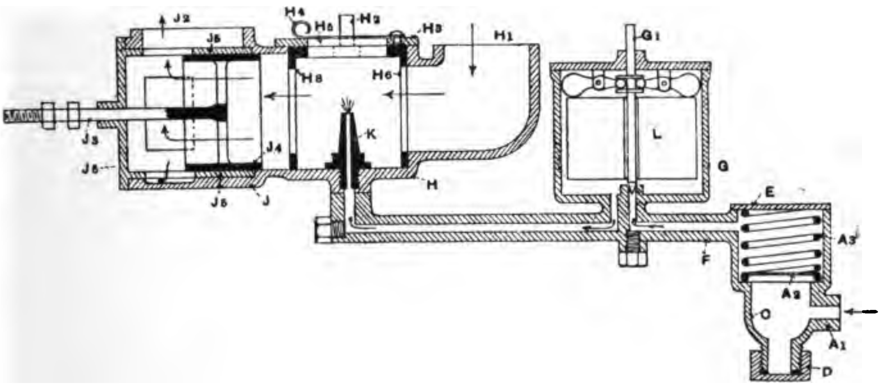


FIGURE 57—NAPIER.

dle, T, is placed in the passage in such a manner that by raising and lowering the rod the area of the air opening at the gasoline jets may be varied in proportion to the speed of the motor. It will be very easily seen that at the time of starting only a small amount of air is allowed to pass into the motor, this, of course, giving a rich mixture. On the other hand, when the engine speeds up, the lever, I, may be made to raise the cone up into a position which will allow a large amount of air to pass through. This carburetor is equipped

with a hot water jacket, R, which is very often applied to carburetors in order to facilitate the vaporization of fuel. In cold weather this arrangement is often very advantageous. Many carburetors, however, do not use this device, but depend upon taking the air from around some heated portion of the motor. Frequently

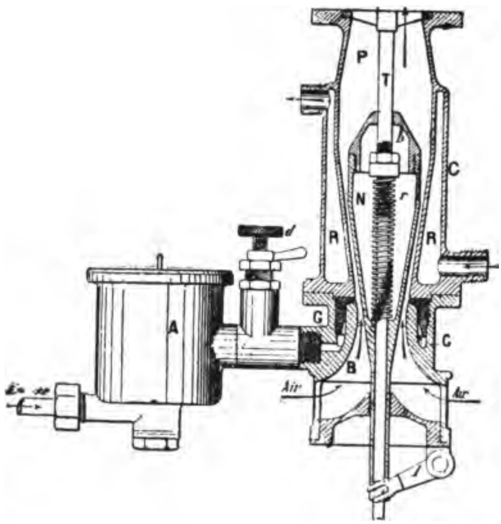


FIGURE 58—DECAUVILLE.

the inlet and exhaust "headers" are cast together in such a way that the incoming air must pass along the heated surface of the exhaust pipe before entering the carburetor proper.

Another very well-known foreign carburetor is shown in Fig. 59. There are several items of interest in this carburetor. The gasoline, as you can see, rises

up through the tube, D. Here it is met by the incoming air entering the pipe, A, and carried on into the motor, through the pipe, J, a sliding piston, attached to the governor, regulating, however, the amount used.

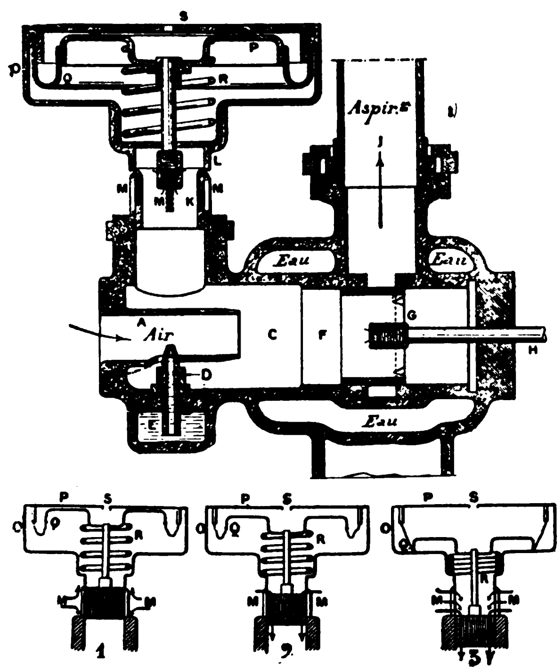


FIGURE 59—KREBS.

When additional air is desired, the suction created causes the small piston, K, to descend. In doing so, ports M, in the side of the wall, are opened, and additional air is drawn in, the amount depending upon the position of the piston.

Nos. 1, 2 and 3 show three positions of the piston. 1, the closed position; 2, showing the ports partially opened; and 3, representing the piston at its lowest point of travel, with ports wide open. The piston is controlled by a spring and diaphragm in such a manner that the upward and downward movements are comparatively gradual and no chattering effect is noticeable.

ALCOHOL CARBURETORS. Many attempts have been made to design alcohol carburetors, and some inventors have been fairly successful. All, however, are very much alike, the greatest difference being in the arrangements for heating the mixture. Many of the alcohol carburetors are built in such a way that both gasoline and alcohol may be fed through the same mixing chamber. The motor may be started on gasoline, and the temperature of the cylinder raised to a sufficiently high point to vaporize the alcohol when this fuel is used.

One very common type is made with two float chambers and two fuel nozzles so arranged that in starting the explosive gas may be drawn from the gasoline slide first, and later on, when the alcohol is to be used, a small valve in the mixing chamber may be shifted in such a way as to allow the gasoline to be entirely shut off, and the alcohol introduced. The principal trouble with alcohol is that it is rather hard to vaporize, and therefore nearly all of the so-called alcohol carburetors contain some device for utilizing the heat of the exhaust gases or cooling water to assist in the vaporization of the fuel.

Nearly all the automobile engineers are working on the alcohol carburetor proposition, and in all probabil-

ity several will be put on the market this year which will be successful.

Kerosene and heavy oil carburetors differ from the regular vaporizer in that a provision is made for heat-

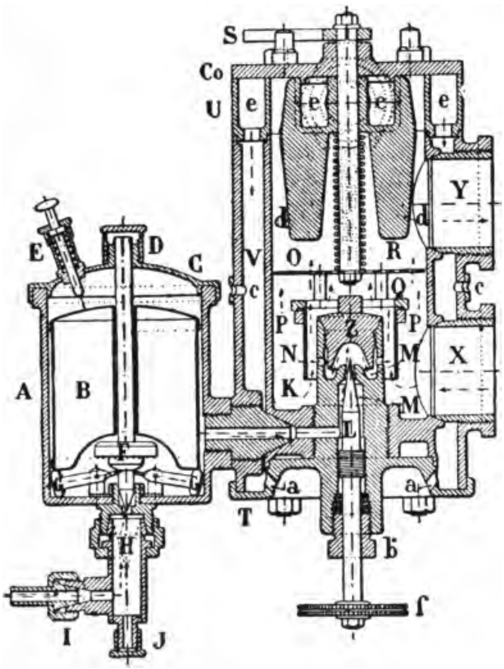


FIGURE 60—LONGUEMARE (ALCOHOL).

ing the fuel by means of the exhaust gases or some other external source, so that the oil will be raised to a sufficient temperature to insure an accurate mixture. If this is not done the oil is liable to "crack" or decompose and leave a deposit on the inside of the cylinder wall.

A well known kerosene carburetor of comparatively recent design is shown in Figure 61. You will notice that provision is made for heating the mixture and a peculiar type of spraying nozzle is used.

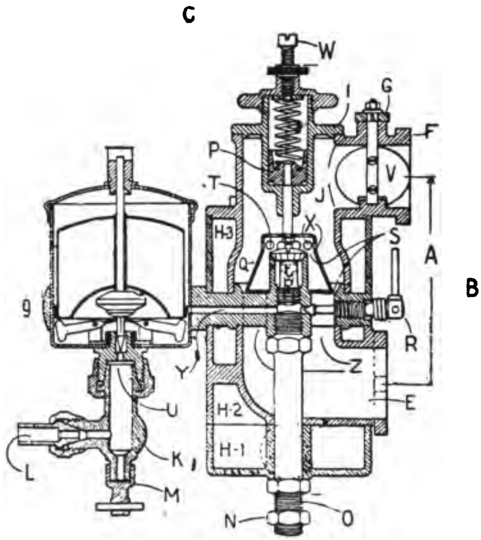


FIGURE 61—KING (KEROSENE).

IGNITION

In taking up the subject of Ignition, the writer will not attempt to define the word "electricity;" neither will hê go into the theory of the whys and wherefores of this mysterious agent. He will, however, attempt to define, in simple language, some of the terms used in connection with electrical measurements.

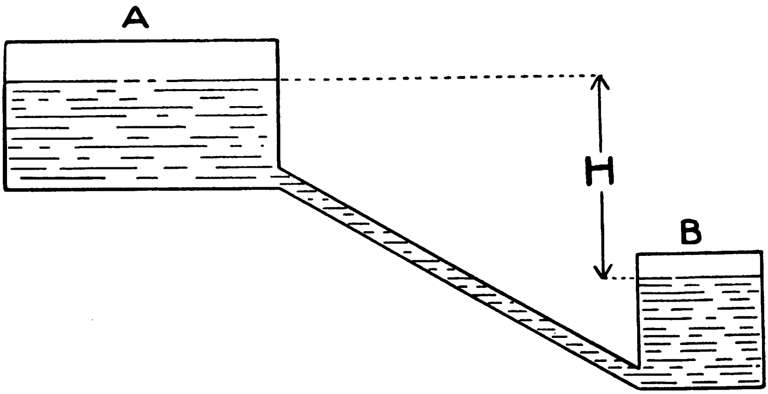


FIGURE 62.

ELECTRICAL UNITS. The flow of the electric current may, in many ways, be compared with the flow of liquids, for instance, supposing we consider two systems, running side by side, one a wire carrying a current of electricity, the other a pipe carrying a certain amount of water. In the first place, the pressure will depend, in the case of water, upon the difference in level between the upper and lower end of the pipe. In the case of electric current, it will be measured by the difference in potential, as it is technically called, be-

tween the source of supply and the point at which the reading is taken. Thus you can imagine that a dynamo or battery might represent a water pump, which, by having power applied to it, will produce a pressure, and hence cause a flow of water, the quantity and pressure of which might be compared to that of an electric current. While these analogies are not strictly true, yet at the same time very good ideas may be formed of the flow of an electric current by such comparison.

The amount of current flowing, or the rate of flow, as

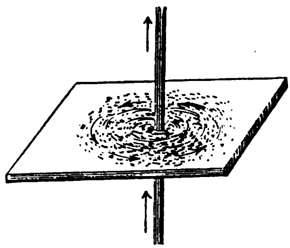


FIGURE 63.

it is commonly called, may be compared to the amount of water flowing out of the pipe in a given length of time. Another unit of measurement used in electricity is the unit of resistance, this, of course, being very similar to the frictional resistance found in water pipes. The following table will help to keep in mind the various units and their similarity to those used in hydraulic measurements.

Volt—Unit of Pressure—Caused by difference in potential.

Pounds per square inch—Unit of pressure—Caused by difference in level.

Ampere—Unit of rate of flow—Dependent upon voltage and resistance.

Gallons per minute—Unit of rate of flow—Depending upon pressure and frictional resistance.

Ohm—Unit of resistance—Depending upon diameter, material and length of wire.

Co-efficient of friction—Unit of resistance—Depending upon diameter, material and length of pipe.

These relations, as before mentioned, are not strictly true, yet at the same time they are given in the hope that they will give the reader a somewhat clearer idea of the meaning of these electric units.

In any case, where there is no self induction, the relations existing between these units may be expressed as follows: The voltage is equal to the resistance multiplied by the amperage, or in other words, the resistance will be found equal to the voltage divided by the amperage.

Another relation which may possibly prove interesting, is that voltage multiplied by amperage is equal to watts, the watt being the unit of power.

Volts multiplied by amperes equal watts.

Seven hundred and forty-six watts equal one horse power, or 33,000 foot pounds per minute.

Thus, you can see, that electrical power may be very easily reduced to a mechanical equivalent or vice versa. This relation should be remembered, as later on it will be again used when the question of horse power determinations is taken up.

The only other characteristic of an electric current which we shall attempt to consider, is that of induction. Physicists have found that by passing an electric cur-

rent through a wire, a certain effect is produced in the ether surrounding it. This may be easily shown by passing a wire through a cardboard upon which has been sifted a few iron filings. As soon as the current is turned on, these filings will arrange themselves in various shapes, showing very plainly that a "magnetic

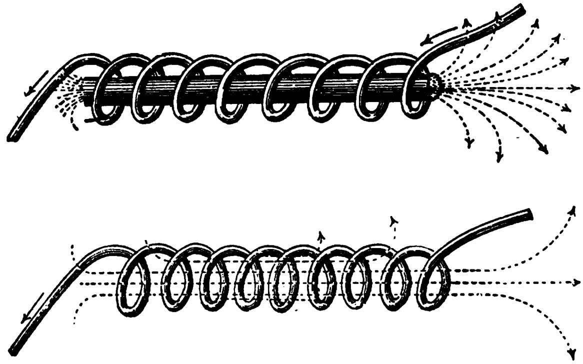


FIGURE 64.

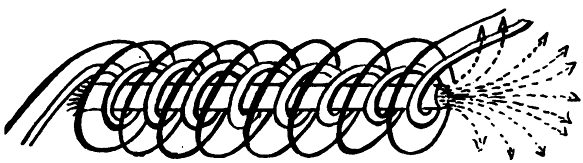


FIGURE 65.

field" has been created. Other scientists found that by winding this wire into the form of a helix that a field of different form was created. In addition to this they found that a bar of iron placed in the center of the helix would concentrate this magnetic field and make it stronger inside the coil. They also discovered that the iron itself became magnetized; one end became

what was called a positive pole, the other a negative pole, this nomenclature arising from the fact that certain electrified bodies were repelled by one end, attracted by the other.

Another curious fact which was later evolved was

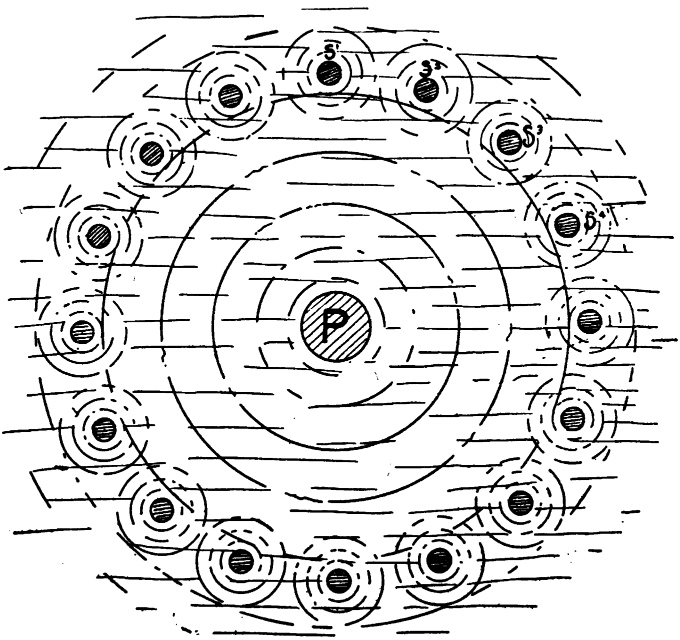


FIGURE 66.

that upon winding another coil of wire around the first one, that every make and break of the current in this first, or primary coil, as it is called, produced a current in the outside or secondary coil. This quality of the electric current is what is known as induction. A clear idea of this may be obtained by imagining something like this: Consider a body of water in the center of

which there is a large open space, and around it, placed at regular intervals, a number of posts projecting above the surface of the water. Now, let us drop some heavy object in the center of the open space, thereby creating a number of large waves radiating from this point. If you will note the progress of the various rings carefully, you will see that a wave striking one of the smaller posts is immediately broken up, and a set of ring waves begin to emanate from each post; all of the energy of the large wave having been divided up into a great number of smaller rings. Now, if you can conceive that a similar action has taken place in the ether above the electrical conductor, you can form some idea of the meaning of electrical induction.

SOURCES OF ELECTRICITY. Although there are several ways of producing an electric current, yet the two methods now in general use are by chemical action, and the direct conversion of mechanical energy into electricity. Under chemical action comes the ordinary galvanic cell, dry cell and storage battery. Under the second heading may be classed dynamos and magnetos.

The wet and dry cells produce an electric current by chemical action, while the storage cell simply acts as a reservoir for a certain amount of electrical energy, the ingress and egress of which is accompanied by chemical action.

The simplest form of an electric cell consists of two elements, such as carbon and zinc, or zinc and copper, immersed in a bath of an exciting fluid, such as sulphuric acid and water.

The dry cell is a slightly modified form put up in such a way that the contents will not spill. The elements ordinarily used in this form of cell are carbon

and zinc, the walls of the cell furnishing the zinc element, and the carbon stick in the center the other.

The exciting fluid, or "electrolyte," is a mixture of ammonium chloride (sal ammoniac) and water; this is usually mixed with plaster of paris in order to make it a semi-fluid mass. In addition to this a mixture of carbon dust and black oxide of manganese is put in, which

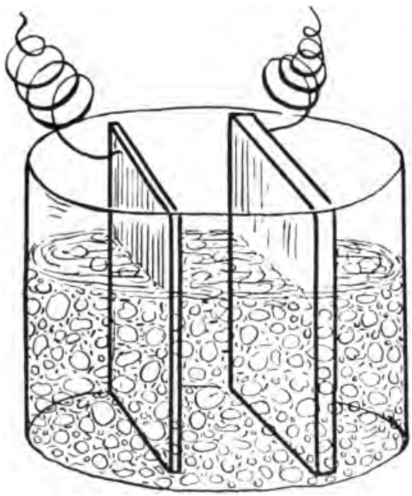


FIGURE 67—A "WET" CELL.

acts as a "depolarizer." This last addition is necessary for the reason that when two elements are immersed in the exciting fluid, a chemical action immediately begins to dissolve the zinc, and the result is that free hydrogen gas is liberated at the carbon element. If this is allowed to accumulate it soon covers the surface of the element, and interferes very materially with the action of the cell. This is called polarization. In order to overcome this effect, black oxide of manganese

is introduced. It has a very strong affinity for hydrogen, and therefore prevents the hydrogen from forming in very large quantities.

One formula used in making up dry cells is as follows:

¼ pound zinc oxide.
¼ pound sal ammoniac.
¾ pound plaster of paris.
¼ pound chloride zinc.

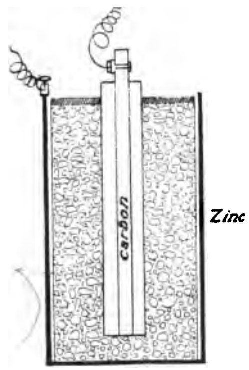


FIGURE 68—A "DRY" CELL.

Mixed to a consistency of paste by adding one-half pint of water.

This mixture is packed in closely around the carbon stick, and the whole cell is covered with tar or paraffin.

STORAGE CELL. The storage cell consists of a number of roughened lead plates immersed in a liquid usually consisting of sulphuric acid and water. The plates are chemically treated so that when an electrical current is turned into the cell a chemical action imme-

diately takes place. When the cell is fully charged, a condition determined by the appearance of the liquid and the time and current used in charging, a certain amount of the materials in the cell will have been converted into a different form. Upon discharging the cell again a reverse set of operations takes place, and the constituents resume practically their original state.

FIGURE 69.

The chemical reactions in the storage cell are rather complex, and we will not attempt to explain them further. Sufficient to say a storage cell simply acts as a reservoir for the current and makes a very convenient source of supply of electricity for use in automobiles and other power plants using electricity either directly or indirectly as a source of power.

Fig. 69 shows a typical form of storage cell, with its accompanying charging outfit.

When a large current is desired a great number of

cells are made up together and connected in such a manner that one or all may be used at any time.

FIGURE 70—A STORAGE BATTERY.

DYNAMOS AND MAGNETOS. The third means of producing an electrical current is by the use of a magneto or dynamo. In the case of the dry cell, or storage

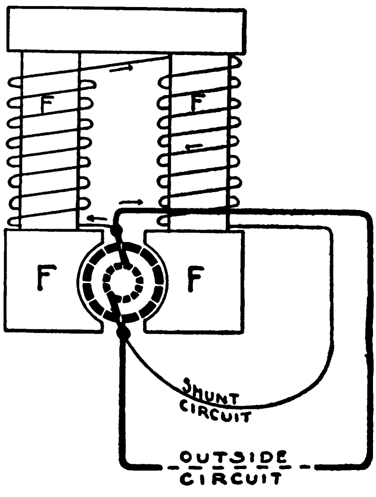


FIGURE 71—DIAGRAMMATIC SKETCH OF DYNAMO, NOTE SHUNT CIRCUIT FOR MAGNETIZING FIELD MAGNETS F. F.

battery, the electrical current is produced or liberated by chemical action. In the dynamo, however, there is a direct conversion of mechanical energy into electrical energy.

Figs. 71 and 72 show diagrammatic sketches of the dynamo and magneto respectively. You will note that

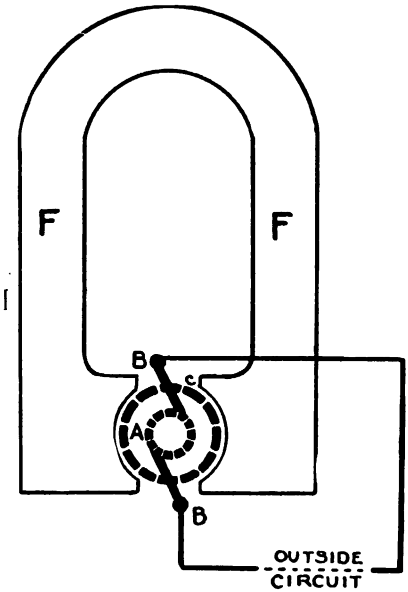


FIGURE 72—DIAGRAMMATIC SKETCH OF MAGNETO, NOTE ABSENCE OF SHUNT WIRE.

in the dynamo the field magnets, FF, are magnetized by means of a small current flowing around a "shunt" circuit; that is, a certain amount of current is taken from the system and used to magnetize the field. The remainder of the current generated is used in the outside circuit. In the case of the magneto you will note that no such arrangement is necessary owing to the fact

that the field magnet is made of steel, and permanently magnetized.

With this very short explanation of the difference between a magneto and dynamo, let us look at the general theory upon which they work. It has been found that when a wire is made to cut through an electrical field that a current will be created in the wire, therefore, in order to develop a certain amount of electrical energy, it is only necessary to provide an electrical field, and a number of conductors so arranged that they may be made to cut through these lines of force. For instance, if we assume that the two poles FF are magnetized, so that one is a south pole and the other a north pole, we know that there will be certain lines of force reaching from one to the other, that is, the intervening space may be termed an "electrical field." Now, if we wind a number of wires around a cylinder, or armature, as it is called, and revolve that cylinder between two poles, you can see that every time one of these conductors move, it cuts a line of force. This, as before mentioned, creates an electrical current in the wire in a certain direction, depending upon the direction of the rotation of the armature, and the way in which the wires are wound around it. These small currents will differ in direction of flow, and therefore an attachment must be provided which will correct this, and give a continuous current flowing in one direction.* This is done by means of a commutator and set of brushes.

The amount of power developed in a dynamo will be proportional to the size of the wire, the strength of the

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*For further explanation you are referred to any good book on Physics or Electricity.

magnetic field, the number of turns of wire on the armature, and the rapidity with which these wires cut through the magnetic field, or, in other words, the number of revolutions per minute of the armature. Having knowledge of these various quantities, it is an easy

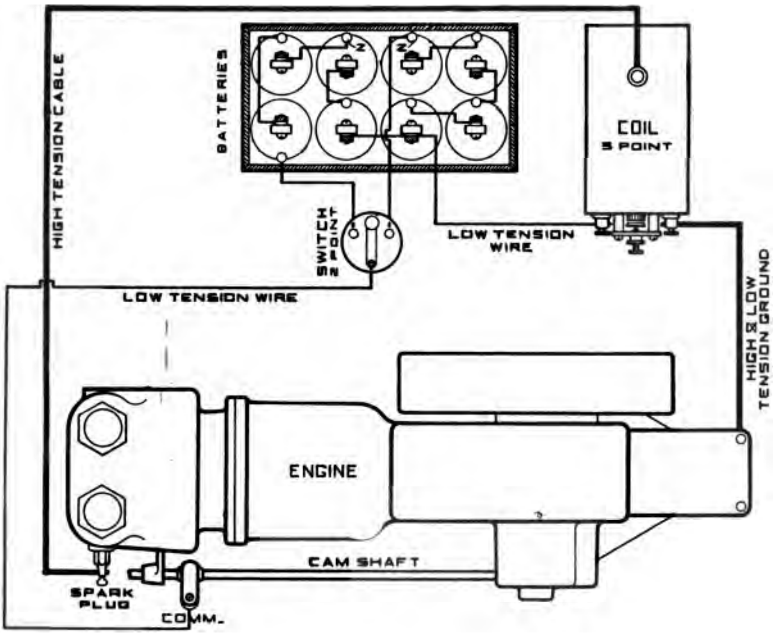


FIGURE 73—A SINGLE-CYLINDER WIRING DIAGRAM.

matter to design a dynamo or magneto which will deliver a certain current at a certain voltage, when running at a certain number of revolutions per minute.

Other details relative to the use of dynamo and magneto will be given later, when some of the actual machines in use are considered.

THE INDUCTION COIL. You will remember that in

the former description of induction, it was found that when two coils were wound one around another and a circuit was made, or broken, in the inner or "primary" coil, another induced current was created in the outer or "secondary" winding, whose voltage and amperage depended upon the sizes and number of turns of wire in the two coils. It was also noted that the introduction

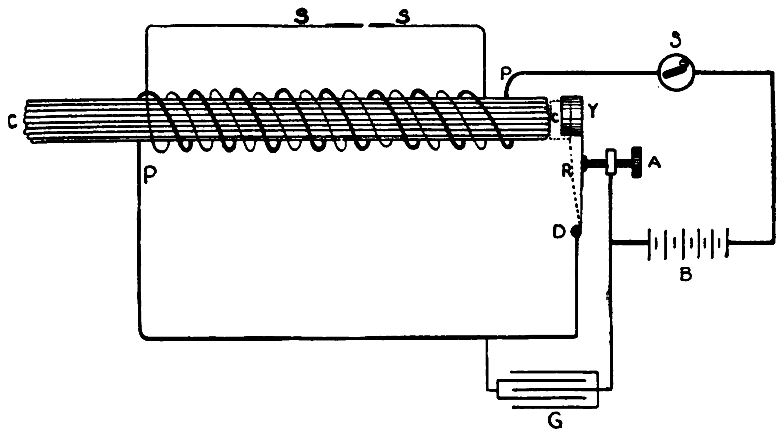


FIGURE 74—A FOUR-CYLINDER WIRING DIAGRAM.

of a soft iron core magnet into the inner coil concentrated the magnetic field to a great extent inside of a primary coil.

Fig. 74 shows a diagrammatic sketch of an induction coil. CC represents the iron core composed of soft iron wires. PP is the primary winding, and SS the outer or secondary winding. You will note there is absolutely no connection between these two coils, and, as a matter of fact, they are carefully insulated by paper or rubber placed between the two coils. Y represents a vibrator, the use of which will be explained later. S is a switch used for opening and closing the

circuit, and B represents a battery of five cells. A is an adjusting screw, the point of which rests against a platinum point R soldered upon the vibrator.

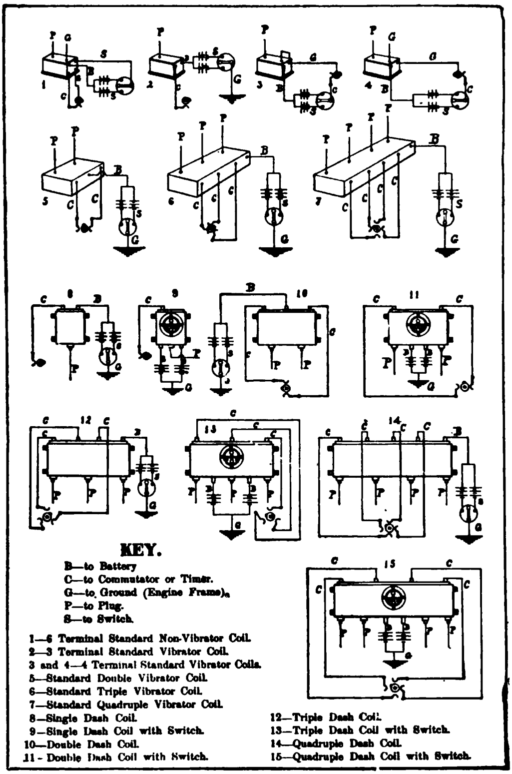


FIGURE 75—WIRING DIAGRAMS.

If the switch S is closed, the electric current generated by the battery B will travel through the primary winding. This will cause the core CC to become magnetized, and the vibrator Y will at once be drawn towards it. This will break the connection at R. The

core, being made of soft iron, immediately upon the interruption of the current, will again lose its magnetism, and the vibrator will return to its original position. Then, of course, the circuit will again be closed and the same operation will be repeated. Thus, you will note that the current will be made and broken very rapidly, and as a result, induced currents will be created in the secondary winding. The current in the secondary will be very much higher in voltage than the original current produced by the battery, and is the one used for ignition purposes. As the number of turns of wire and the size is determined when the coil is built, there is practically no adjustment which can be made upon any part of the coil except vibrator. The rapidity with which the current is made and broken is determined by the stiffness of the vibrator spring, and this, in turn, is controlled by the adjusting screw A. Therefore, when it is desired to adjust the coil, all that is necessary is to loosen the adjusting screw A and turn it in and out until the spark between S and S1 is "fattest."

When an induction coil is used in connection with an automobile engine, a device called a commutator is used for automatically closing the circuit when a spark is desired. This automatic switch or commutator is operated by the engine itself, and so timed that it will close the electrical circuit at the time required for igniting each fresh charge of gas. Commercial coils are equipped with special devices and slightly modified schemes of wiring, but they all work upon the same principle and will be very easily understood after a few minutes' examination. Very often one secondary wire is connected to one of the primary "binding posts," the object being to do away with one extra wire.

The typical coil consists, as has been said before, of a bundle of soft iron wires around which is wound the primary wire. In order to keep this wire in place two wooden or hard rubber blocks are placed one on each end, making a spool which may be placed in a lathe for

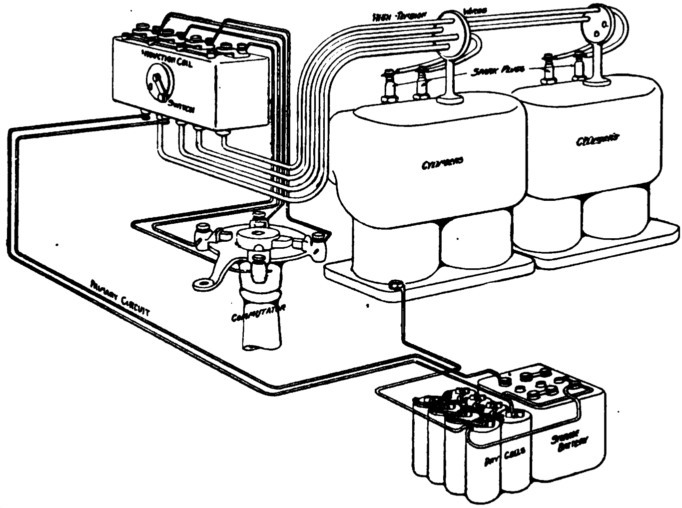


FIGURE 76.

easy winding. Around this is placed a few turns of paper treated with paraffin or a rubber tube, this serving to insulate the primary from the secondary layers. Around this the secondary coil is wrapped. Sometimes, in order to make the secondary coil removable, it is made in two separate sections, each of which is wound on a separate rubber spool, and slipped on over the other winding. Thus it is a very easy matter, when a short circuit occurs, in the secondary winding, to remove the defective coil, and substitute another.

The whole coil is placed in a box or tube, and the remaining space filled in with an insulating material, such as beeswax, or some similar substance. The terminals of the two windings are brought out through holes in the side of the box, and connected with the binding posts, fastened on the outside. Very often, when it is desired to connect one secondary wire and primary wire to the same binding post, this connection is made inside of the case, and very carefully protected by means of the insulating material.

The case is screwed to a base board, and connections

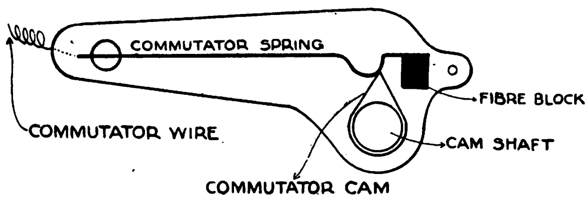


FIGURE 77—A SINGLE-CYLINDER COMMUTATOR.

to the vibrator are made, various forms of which may be seen in the illustrations.

In addition to this, all modern, up-to-date coils are equipped with some form of condenser, indicated in Fig. 74, at "G." This condenser consists of alternate layers of tin-foil and insulating substance, such as paraffin paper. Every other layer of tin-foil is connected to the wire on the right side, and the remaining layers to the wire on the left side, in such a manner that there is absolutely no connection between the two sets of sheets. The condenser acts as a storage for the electric current. The principle upon which it works can be compared with that of the action of the air dome

in an hydraulic system. The effect of placing it between the contact points of the vibrator is that the sparking is eliminated between these points, thereby decreasing the tendency to foul the contact surface. This condenser, after being made up and properly connected, is placed in the lower part of the coil box, and completely surrounded by the insulating wax used about the coil.

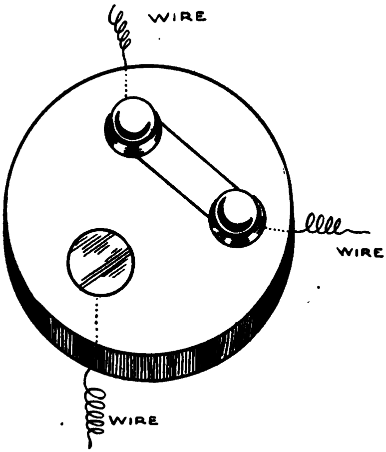


FIGURE 78—A TWO-POINT SWITCH.

THE JUMP SPARK SYSTEM. Now that we have stated the action of the induction coil, let us see how it is applied in actual practice. In a gas engine it is necessary for the charge to be ignited at regular intervals, and therefore it is the office of the electrical sytem to provide such a means of ignition. The current is furnished by the battery, and must be controlled automatically by a switch so that the current is connected at the proper time. This is accomplished in the mod-

ern gasoline motor by an automatic switch called a "commutator."

The commutator generally consists of a revolving

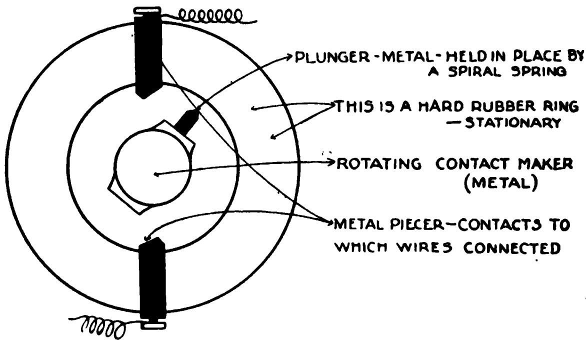


FIGURE 79—A TWO-CYLINDER COMMUTATOR.

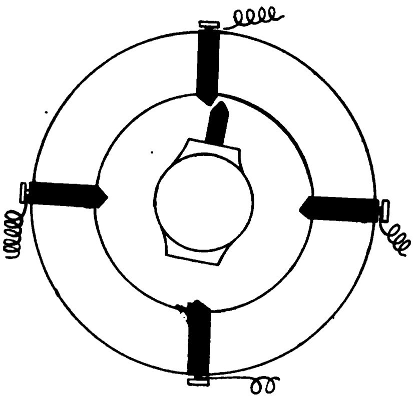


FIGURE 80—A FOUR-CYLINDER COMMUTATOR.

segment, which at one or more points in its rotation connects with an outer stationary part, thereby completing the electric circuit.

For a single cylinder motor, the form usually used is similar to that shown in Fig. 77. It consists of a cam driven by the engine, which touches at the proper moment a spring placed at a short distance from it.

If the engine is one of the single cylinder four-stroke cycle type, this contact is made once in every two revolutions, and hence the cam is mounted upon a cam shaft which revolves at half the speed of the main shaft, this arrangement being made possible, as you will remember, by the use of either worm or spur gearing.

In the two-stroke cycle motor, the contact is made once every revolution, and therefore the commutator may be placed upon the main shaft, itself.

For two-cylinder motors another contact, diametrically opposite, may be arranged so that the commutator assumes a form similar to that shown in Fig. 79. For three-cylinder motor, three contacts are provided, placed 120 degrees apart. For four-cylinder, four contacts are needed, 90 degrees apart. There are various modifications of these forms upon the market, but all operate upon the same principle, and will be easily understood upon studying the mechanism carefully.

In addition to the commutator, an ordinary switch is provided, and placed in the primary circuit, at some convenient place, so that the current may be turned off when the motor car is not in use. Fig. 78 shows a form of switch used. You will note that there are two points instead of one, the second being provided for an auxiliary set of batteries, so that in case one set runs out, the other set may be instantly put into service. You will note in the wiring diagram shown in Fig. 73 that

four cells are connected to one point of the switch, and four to the other.

When the commutator effects a contact between the cam and the commutator spring, the circuit is closed. The current travels from the battery through the primary winding of the coil out through the coil to the engine, through the engine and cam shaft to the commutator cam, from the commutator cam to the cam spring, from the spring through the outside wire back

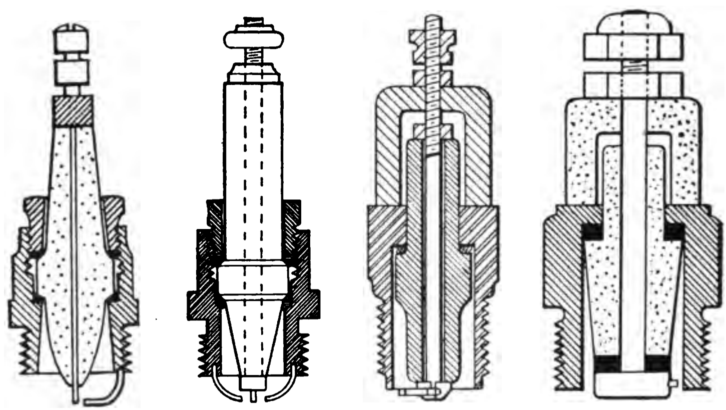


FIGURE 81—FOUR FORMS OF SPARK PLUGS.

to the switch, and from there to the other terminal of the battery. This completes the primary circuit.

Simultaneously with the closing of the primary circuit the vibrator begins to act, and induced currents of high voltage are created in the secondary system. As this is the current used for ignition purposes, all that is necessary to do is to provide for two points inside the cylinder between which a spark may be caused to pass. This may be done in two ways. Either by screwing into the cylinder wall a "spark plug" con-

taining two insulated points, to which the secondary terminals may be connected, or by introducing another form of spark plug which consists of one insulated point surrounded by a threaded collar. In this case only one secondary wire is connected to the spark plug, and the other one is attached to some part of the motor. This is the common form used, as only the one wire is needed, the engine itself acting as the other conductor. The current in the secondary system will pass from the coil to the engine, through the spark collar across the gap into the engine to the central insulated wire, and out through the secondary "lead wire" back to the coil. Fig. 81 shows a few of the spark plugs in use at the present time. You will note that they are very similar in form, the main difference being the shape and material of the insulating tube, and sparking points.

Very often, in order to make sure that the spark occurs regularly in the combustion chamber, an auxiliary "spark gap" is introduced into the secondary circuit in such a position that it may be placed upon the dashboard in full view of the driver. This will not only show whether or not the spark is taking place, but has a tendency to make the spark somewhat larger.

If you will very carefully go over the wiring system of any car, the above explanation will soon be clear. In most cars, you will find that only one secondary wire is used, one primary and the other wire being combined in such a way that a single conductor is made to carry both currents. This wire, you will find, is always connected to the motor, and is generally called the "ground wire."

TIMING THE SPARK. In order to obtain the greatest amount of power from every working stroke of

the motor it is necessary to ignite the charge in the cylinder at such a point that the maximum pressure will be reached just as the piston is beginning its working stroke. It is therefore necessary to make allowances for the varying speeds of the motor, and so construct the ignition apparatus that the "time of contact" may be made earlier or later as the conditions may require.

For this purpose a control lever similar to the one used in connection with the carburetor throttle is provided. This lever is connected with the commutator and by its movement the contact point or points may be shifted to an earlier or late position, making it possible to ignite the charge quite a considerable time before the piston reaches its "head end" position. The fuel, contrary to current opinion, does not explode, but instead burns very rapidly taking a certain amount of time to develop its maximum pressure. Account is taken of this characteristic, and the spark is "timed" accordingly. When the engine is running slowly the ignition takes place approximately "on center" that is just as the piston is starting on its working stroke, but when the motor is "speeded up" the time of ignition may be "advanced" so that it occurs some time before the piston reaches the end of its compression stroke. Any advance beyond this proper point, however, ignites the gas too soon, and causes what is known as a "knock" in the cylinder, a thing which produces both a disagreeable jolting of the car, and a harmful effect on the motor.

THE MAKE AND BREAK SYSTEM. This system is perhaps one of the simplest ignition systems in use. A battery, or other source of electricity, a primary coil,

and a mechanical make and break apparatus constitute the essential parts in this mechanism.

The only part requiring explanation is the make and

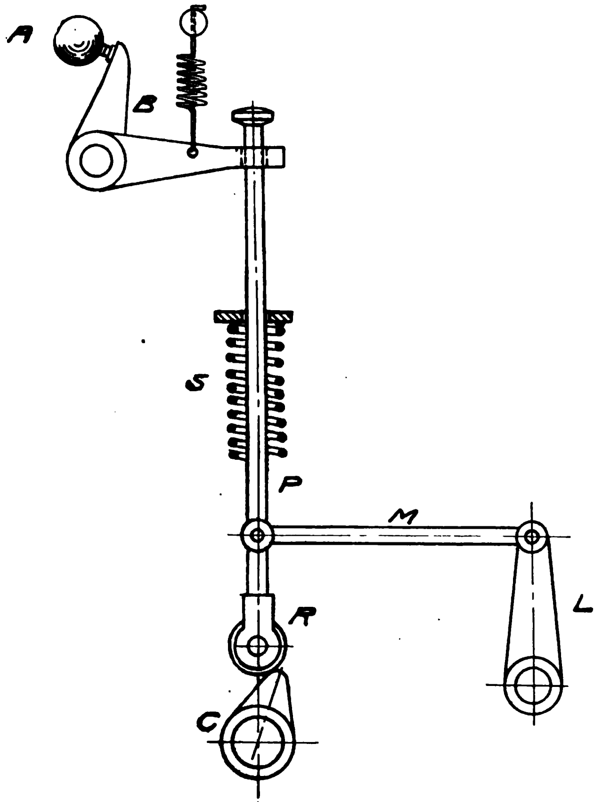


FIGURE 82—A "MAKE AND BREAK" SYSTEM.

break apparatus. It consists of a stationary member "A" called the "anvil" and a rocker arm "B" called the "hammer." These two pieces are mounted on a plug which fits into a hole in the side of the cylinder.

Both the hammer and anvil are equipped with points similar to those used on the spark plug.

When it is desired to produce a spark the two parts are brought together and then suddenly allowed to spring apart. The cam "C" turning in the direction of the arrow causes the plunger "D," which is held down against the cam face by the spring "S," to rise. This in turn forces the point of the rocker arm "B" against the corresponding point on the anvil "A." This contact continues until the highest point of the cam "C" passes under the roller "R." Then the plunger, being suddenly released, falls rapidly, causing the rocker arm to spring back to its former position, and in so doing produces a spark between the igniter points. The levers L and M connect with the spark advance lever. A movement of this shifts the roller R to the right or to the left, thereby causing the spark to occur later or earlier as conditions may warrant.

MAGNETOS. Magneto systems may be divided into two groups, the "Low Tension" and "High Tension," and these again may be subdivided into two classes.

THE LOW TENSION SYSTEM. In the first type of the low tension system there is only a primary winding on the armature, and no coil is used. The break in the current at the spark plug is made just as the intensity of the current in the armature winding reaches its maximum. A system of this character is employed in the Mercedes.

In the other low tension system a commutator is used in connection with the magneto, and the current can be broken at any time desired, and not necessarily at the time when the height of the electric wave is reached.

THE HIGH TENSION SYSTEM. The first high tension system uses an armature having two windings instead of one, a primary of large wire, and a secondary of fine wire which is wound around the primary. The magneto is equipped with a mechanical or magnetic "breaker" which is used to obtain the "inductive" effect in the secondary winding. No coil is necessary for the operation of this device. Well known systems employing this principle are the Sims Bosch, Splitdorf and Gianoli.

The other high tension designs make use of a low tension magneto which furnishes a current to an induction coil equipped with a mechanical breaker, this breaker in the primary producing the inductive effect in the secondary winding of the coil. The Eisman and Holley ignition systems are modelled along this line.

PRINCIPLES OF A MAGNETO.* A magneto, so far as its essential parts are concerned, is a very simple thing. It consists of a U shaped piece of special steel, which is permanently magnetized; in other words, a common horseshoe magnet and a rotating armature. The armature consists of a soft iron core of approximate H cross section as viewed along the shaft upon which it is supported and on which it is designed to rotate. The magnet, to the free ends of which are affixed soft iron arc shaped pole pieces, and the armature core with the sides of the H correspondingly arc shaped, is shown in vertical section in the figure. In the slot formed in the armature core by the sides of the H, wire is wound in turns lengthwise of the armature shaft. So much for the construction of the elementary magneto. In order to understand how it gen-

*Reprinted from literature issued by Holley Bros.

erates in its armature, when turned, an electric current, it is necessary to remember one law of physics, namely: Whenever a wire is wound about a mag-

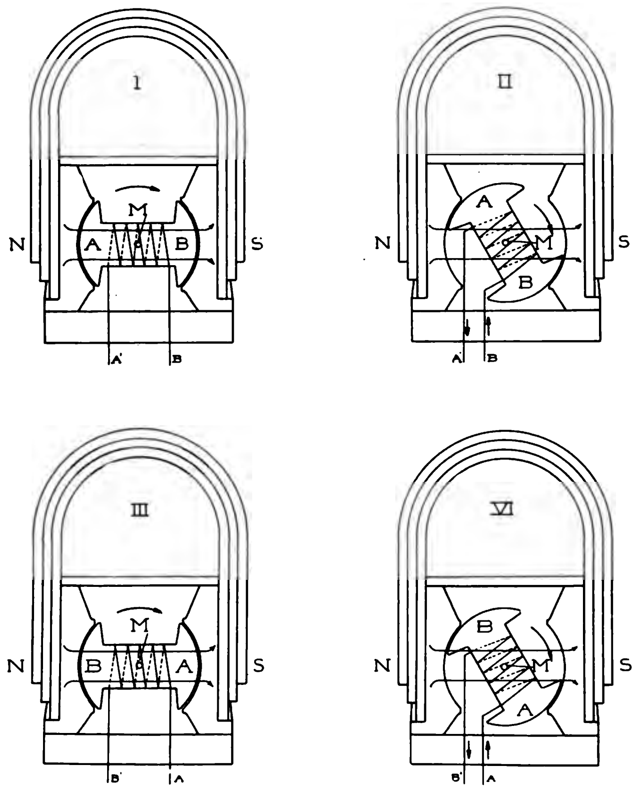


FIGURE 83.

netized soft iron core and the magnetism of the core suddenly dies out, there will be a tendency for a current to be produced in the wire. A familiar example of the working of this law is found in the operation of the common jump spark coil. Here we have a core

made of soft iron wires and around it is wound a great many turns of fine wire, the ends of which are connected to a spark plug. The core is also wound with a coil of wire which is supplied with current from a battery, and when this current is flowing, the core is magnetized. When the current from the battery is interrupted, the magnetism in the core suddenly dies out, and, in accordance with the law above stated, a tendency is created for a current to flow in the fine wire coil which is connected to the spark plug and this "induced" current jumps at the plug.

In order to explain how the iron core of the magneto armature with its winding is magnetized and how the magnetism of the core is caused suddenly to die out, it is necessary to refer to the four diagrams of Fig. 83, showing the armature in different positions of rotation with respect to the pole pieces. In diagram (I) the armature is represented with the two heads of its core in close proximity to the faces of the pole pieces. The space between the pole pieces is thus almost completely filled or bridged with iron, and magnetism passes from one pole piece to the other through the armature core, thoroughly magnetizing it. Next consider diagram (II). Here the armature is shown rotated into such a position that one edge of each pole of the armature core is just leaving the vicinity of one of the pole pieces. As soon as this position is passed, the space from pole piece to pole piece is no longer filled with iron, but with air or copper wire, which are not conductors of magnetism. Thus very little magnetism passes from one pole piece to the other and the core is no longer traversed by the magnetic influence and suddenly ceases to be magnetic. This is exactly the

condition prescribed by the above quoted law for the production of a current, and, in fact, when the armature in its rotation leaves position (II), there is a sudden impulse of current produced in the wire of the armature which dies away after the armature rotates a little beyond this position. In position (III), the conditions of armature magnetization existing in position (I) are reproduced except that the armature has changed ends in respect to the pole pieces and the magnetic influence passes through it in the opposite sense, charging it oppositely, so that when the magnetism is discharged in position (IV) the current will be in the opposite direction through the wire of the armature winding. As the armature is turned upon its shaft, there are thus produced, in each complete rotation, two rather short impulses of current of opposite direction nearly corresponding with the instants at which the armature heads, so to speak, "part company" with the pole pieces and are half a revolution apart. During the remainder of the rotation there is no current flowing. It may be readily seen that by connecting one end of the armature wire to the armature core and by connecting the other to an insulated metallic contact segment, carried by the armature shaft, upon which bears a stationary insulated brush, the current impulses may be taken from the magneto for use.

Now as to the practical use of such a magneto for ignition purposes. Since it is only during a small part of the armature rotation that current is being generated, it is necessary to rotate the armature shaft at such a speed that these electrical impulses shall be so timed as to correspond with the periods when ignition is required by some one cylinder of the engine. If

this were not attended to, the ignition periods of the engine might occur during the parts of the armature revolution, when no current was being produced. In order to bring about this result, the magneto and the engine must, at all times, run at a properly proportioned ratio of speeds and the positions of engine, crank shaft and armature must be adjusted right in the first place. If the magneto shaft is geared to the engine at the right ratio and the teeth of the two gears are correctly meshed, the desired result will be brought about. For instance, if the engine be of the four-cylinder, four-cycle type, four sparks will be required for each two crank shaft rotations. Four sparks will be produced for each two revolutions of the magneto, as well, and thus, if the magneto and the engine run at the same speed, the sparks will be numerically correct. If geared to the crank shaft, the crank shaft gear and the magneto gear would have the same number of teeth, and if driven from a two to one shaft, the number of teeth in the two to one shaft gear would be twice as great as the teeth of the magneto gear. By changing the particular teeth of one gear which are in mesh with certain teeth of the other, the current impulses may be made to occur at the moments when the pistons are exactly in the firing positions.

REQUIREMENTS OF SPARK PRODUCTION. The higher the speed of a gasoline engine, the more promptly must its ignition spark be produced in order to cause the full development of the explosive pressure back of the piston exactly at the beginning of the power stroke. The higher the electrical pressure applied to the sparking circuit the quicker the spark will be applied. The faster the engine turns the faster the

magneto geared to it is rotated and the more suddenly the armature core's magnetism is discharged. As the voltage or electrical pressure of the current impulses is in proportion to its suddenness of this discharge of magnetism, the voltage of the magneto rises as the speed rises and reduces the time required for spark production somewhat in the proportion that it is demanded. Furthermore, as at high motor speeds the throttle is, in general, widely opened and the compression under these circumstances is very high at the moment of firing the charge, the increase of voltage produced by the magneto insures a specially hot spark just at the times it is most needed. Highly compressed gas necessitates the application of a high voltage if a discharge of large volume is to be forced through it. In brief, the action of the magneto as its speed changes is inherently such that a less amount of hand regulation is required to give the proper spark time.

There should be, of course, a liberal amount of hand spark timing range provided, even with a magneto, and, in many systems of magneto ignition, this range is provided for by manually altering the time at which the magneto shall generate its maximum voltage. In order to do this, the magneto armature position must be capable of a mutually effected change of angular position in relation to the crank shaft position; that is, the armature must be capable of being shifted angularly on its shaft and still be driven positively. Such a provision requires a connection between the spark shifting lever capable of effecting the necessary changes, and considerable mechanical complication is the usual result. In the Holly magneto, this matter of spark time range is very neatly provided for. The magneto

produces its electrical impulses at an invariable time relation with the crank shaft movement, and each of these impulses, as they increase to a maximum, are allowed to charge a large condenser. By varying the instant at which the condenser is permitted to discharge itself through the coil, the instant at which sparks take place are determined and the mechanical connections from the spark timing lever to the timing device are identical in their arrangement with those used in a battery energized single coil system.

CONDENSERS. It may be well to briefly explain the action of a condenser which can, perhaps, be made clear by means of a hydraulic comparison. Suppose a water pump is connected by pipe and valve to a rubber bag capable of distending under pressure. Suppose the pump is operated and water is forced into the bag, and after a certain quantity of liquid has entered (dependent upon the pressure of the pump) the valve is closed and the pump disconnected. Now, if the valve is opened, there will be a sudden spurt of water from the bag caused by the tension of its walls.

The electrical condenser, when connected to a source of electrical pressure, acts in the same manner. It absorbs a certain amount of electricity dependent upon the electrical pressure of the battery or magneto, and, when the circuit is opened, holds this charge bound within it. When, however, the circuit of the condenser is closed, there is a sudden "rush" of electricity from it and it is this abrupt electrical impulse from the condenser through the spark coil that gives the very powerful secondary discharge. The suddenness of its discharge is a characteristic of a condenser when used in this manner.

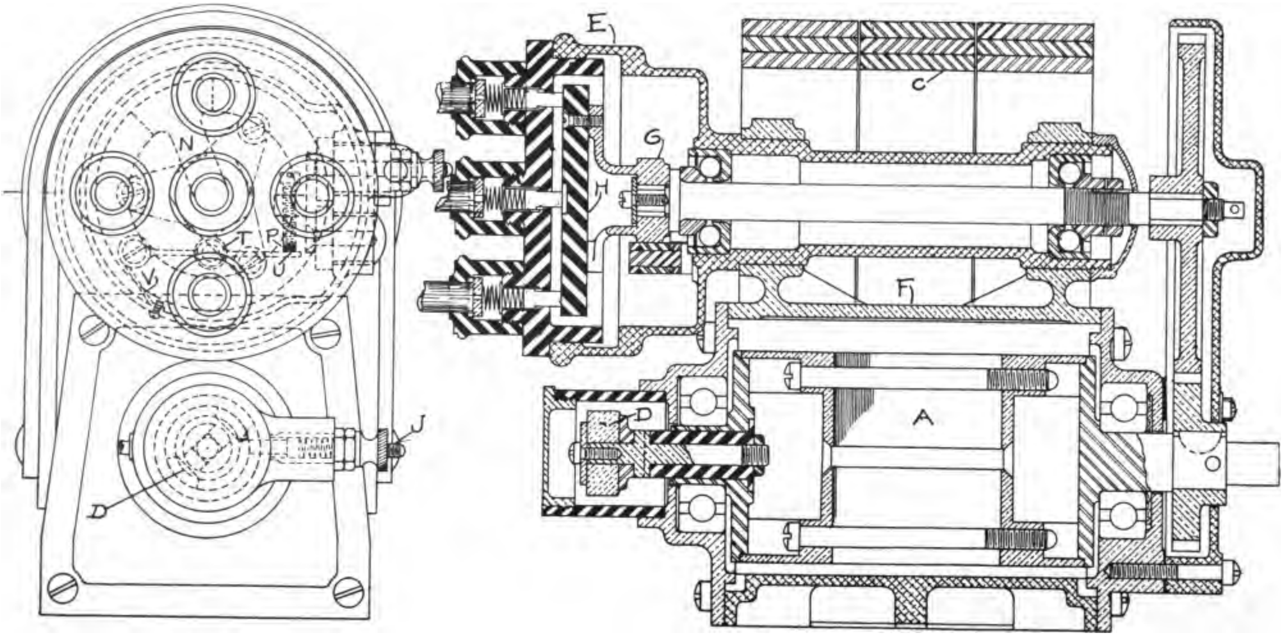


FIGURE 84.

THE HOLLEY MAGNETO. Referring in Fig. 84, (A) represents the armature, the core of which is built up of very thin stampings of exceedingly soft iron, as the use of a solid core or of an inferior quality of metal, renders the electrical actions very slow and inefficient. The armature winding is insulated in the most secure manner from the core, and one end of it is grounded to the armature shaft, while the other is brought out through an insulating bushing to two diametrically opposite brass segments, which are set into the surface of the slate collector ring (D). The whole armature is entirely housed by a bronze casing which positively prevents the entrance of moisture and this housing also fully encloses the collector ring (D). Through the side of this housing passes a spring-pressed brush of carbon rod which alternately contacts with each of the two brass segments. An external binding post leads the current from this collecting brush. The end of the collector housing is closed by a screw plug, the removal of which allows of the inspection of the brush and its contacts. As the contact segments are extremely hard, there is no possibility of metal being carried from them by the brush and the slate insulation becoming fouled. The other end of the armature shaft carries a bronze pinion and its end is extended beyond for the reception of the gear which is to drive it from a mate on the engine. The pinion above mentioned is in mesh with a bronze gear having twice as many teeth, which is mounted upon a ball bearing shaft above and parallel with the armature shaft and carries at its opposite end the combined discharge timer and distributor, which is a feature of this system. These gears are completely housed in an easily removable

aluminum casing. The base of the machine is of non-magnetic alloy and is strongly ribbed upon the underside for the sake of stiffness. The timer and distributor mechanism is contained in a cylindrical aluminum housing (E) which can be rotated upon the end of the distributor shaft housing.

The make and break device which determines the time of discharge of the condenser consists of a steel lever turning at one end upon a horizontal pivot (V). At its other end the lever carries the platinum point (U) and near its middle it bears a hardened steel roller (T). The distributor shaft carries a four-cornered cam (G) upon which the roller just described constantly bears and upon which it is pressed by a spring. Through the side of the distributor housing pass two bushings, upon the internal ends of which are mounted a frame which carries a platinum tipped screw (P) which is adjustable in its support and capable of being locked in position. The location of this screw is such that its point abuts upon the contact point (U). When the four projections of the cam are passing under roller (T) the contact points (P) and (U) are forced apart and at other times they are in contact. The lever carrying the movable contact is connected to the magneto frame and the contact screw (P) is connected to a binding post upon the outside of the distributor housing. Upon a bronze spider which forms the end of the distributor shaft is carried the mica backed fibre disc (H). Upon the front side of (H) is fastened the brass contact sector (N) which rotates with it. The end of the timer housing is closed by means of a hard rubber casing, supplied with five hard rubber brush holding tubes. One of these is cen-

tral in the casing and its spring-pressed carbon brush bears upon the apex of the contact sector (N) at the center of disc (H). The other four brush holders are

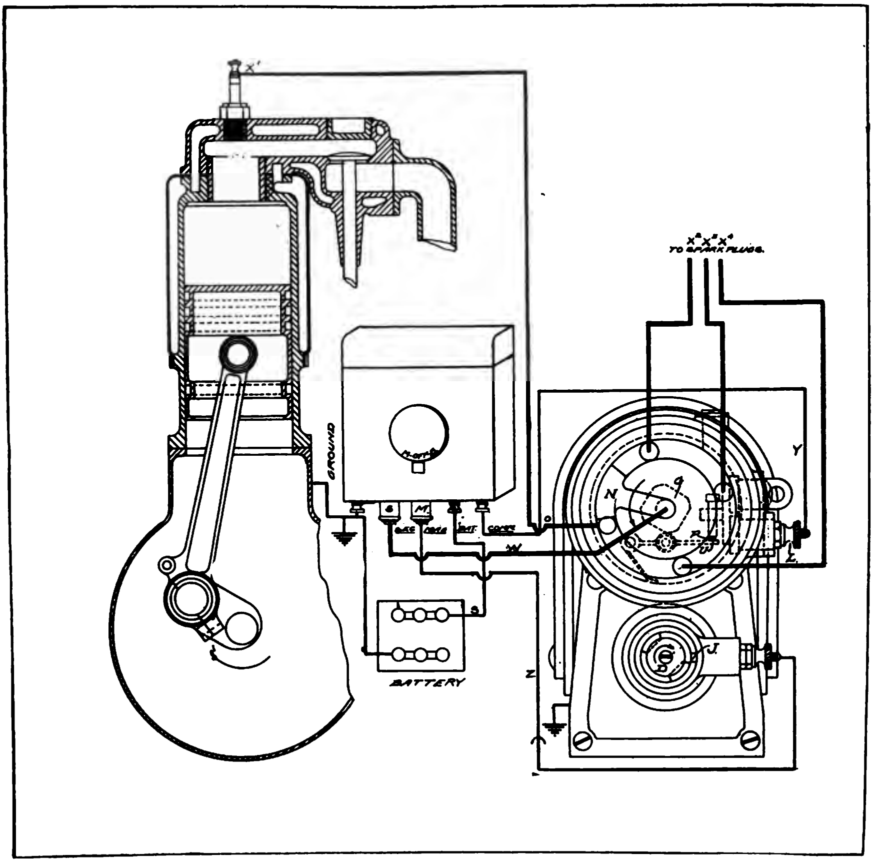


FIGURE 85.

equidistantly arranged near the periphery of the casing and their brushes are arranged so as to be touched successively by the outside edge of contact sector (N),

as it is carried around by the rotation of (H). The center brush holder is wired to one side of the coil secondary and the other brush holders to the spark plugs respectively. It will be noted that the cam (G) and the fibre disc carrying the sector (H) are the only parts mounted upon the shaft, all other parts being attached to and rotating with the distributor housing, which is rotatable by connection with the spark timing lever. The coming together of contacts (P) and (U) and the passage of sector (N) under one end of the carbon brushes leading to a plug are arranged to be simultaneous, and it is clear that moving the distributor housing always varies the time of these to actions equally.

HOLLEY MAGNETO WITH COIL AND CONDENSER. In the operation of this system the electrical actions are as follows: Slightly before the earliest moment at which the spark will be required, one of the collector segments (D) has been passing under its brush. The voltage in the armature during this period is just rising to its maximum and the circuit is this: From the grounded end of the armature winding, through the winding out of one of the segments (D), through its carbon brush and the binding post (J) connected therewith by a wire (Z) to rubber insulated post (M mag) on the coil box, thence to the left hand or magneto contact of the switch, through the switch lever to its upper or common contact, thence to the rear contact of the condenser and out of the condenser by its first contact and brass binding post through a wire to ground on the engine frame.

There is in reality no closed circuit under these conditions, as it is open in the condenser, but the con-

denser plates become charged to a voltage equal to that of the magneto and sufficient current flows into the condenser to effect this. When the contact segment (D) passes from under the brush, this circuit is interrupted and the condenser is left charged at the voltage of the magneto. This must have occurred slightly before the spark (at its earliest point) is required.

Just after this condenser charging connection has been broken, cam (G), one of the corners of which has been holding the discharge contacts (P) and (U) out of contact comes into such a position that the roller (T) follows the flat portion of the cam and contacts (P) and (V) come together. The discharge circuit is thus established as follows: From the grounded pivot (V) of the discharger lever through the contact (V) and (P), through the adjusting screw and support, out of the distributor casting housing by the binding post (L) by a wire (Y) to the brass binding post in the bottom of the coil box marked (common) to the common junction of the primary and secondary coils, thence through the primary coil, out therefrom to the back contact of the condenser and from the front side of the condenser to ground. When contacts (P) and (V) come together the bound charge of the condenser is discharged as a very powerful electrical impulse and passing through the coil primary produces a peculiarly sudden magnetism and demagnetism of its core.

The secondary circuit meanwhile is as follows: From the engine frame to the shell of one of the spark plugs, through the spark gap, out through the live part of the plug by wire (X) to one of the carbon brushes

which pass through rubber posts in the hard rubber front of the distributor housing, the rotating brass sector (N) out through the center binding post of the distributor front by wire (W), to the right hand rubber insulated post on the bottom of the coil box, which is contacted with the free terminal of the secondary coil, thence through the secondary winding to its junction with the primary coil and through wire (Y) and the discharger contacts (P) and (V) which are still in contact to ground. During this action of the igniting, a discharge is produced in the spark plug and ignition is effected. As the high tension sector comes in contact with the carbon brushes of the distributor which are attached to the wires X1, X2 and X3, the other three cylinders receive their appropriate sparks, through exactly the same electrical actions, so far as the charging and discharging of the condenser are concerned. As previously stated, the gearing is such that the distributor shaft runs at one-half the speed of the magneto armature and thus makes one turn in each two revolutions of the engine (or ohe cycle) and thus each cylinder is fired in its proper succession.

THE SIMS BOSCH MAGNETO.* The Sims Bosch magneto comprises a stationary armature mounted between the pole shoes of three powerful horseshoe magnets, and a soft iron sleeve, consisting of a tube having two slots, each representing a quarter of the circumferential area of the tube, that rotate between the armature and the pole shoes. The winding of the armature consists of two coils; one of these coils, which consists of a few turns of thick wire, may be considered to form the primary winding, whilst the other, which

*Reprinted from Sims Bosch catalogue.

consists of many turns of fine wire, may be considered to form the secondary winding.

PRIMARY WINDING. One end of the primary winding is electrically connected with the armature core, whilst the other end is connected with the brass tube 1, which is mounted in the rear portion of the armature spindle, and is insulated from it. The conducting bar 2 is pushed over, and firmly secured to this tube, the end of which extends beyond the spindle of the armature. The primary current is conducted by means of this bar to the contact piece 3, into which is screwed the platinum contact screw 4. The contact lever 5 is pressed against the screw 4 by action of the spring 6 as soon as the lower arm of lever 5, which arm slides on a recessed disc 7 which rotates with the sleeve, falls into one of the recesses thereon. When the lower arm of the lever arrives at the end of the recess, the lever is again withdrawn from contact with the screw 4. One of the terminals of the condenser 20 is connected with the contact piece 3, whilst the other terminal is connected with the body of the machine, the condenser being consequently connected up in parallel with the contact breaker. One end of the primary winding, as already stated, is connected with the armature core, and as the lever 5 is also connected by means of the metal parts of the machine with the armature core, whenever the screw 4 makes contact with the lever 5, the primary circuit is closed through the brass tube 1, the conducting bar 2, the contact screw 4, the lever 5, and the core of the armature, and is broken as soon as the lever 5 ceases to be in contact with the screw 4.

SECONDARY WINDING. This is a continuation of

the primary winding, one of its ends being soldered to the end of the latter, whilst its other end is connected with the small insulated tube 8. The bent carbon holder 9, which passes through the rear portion of the armature spindle, is fitted into the brass tube 8 by means of a small plug, which conducts the second-

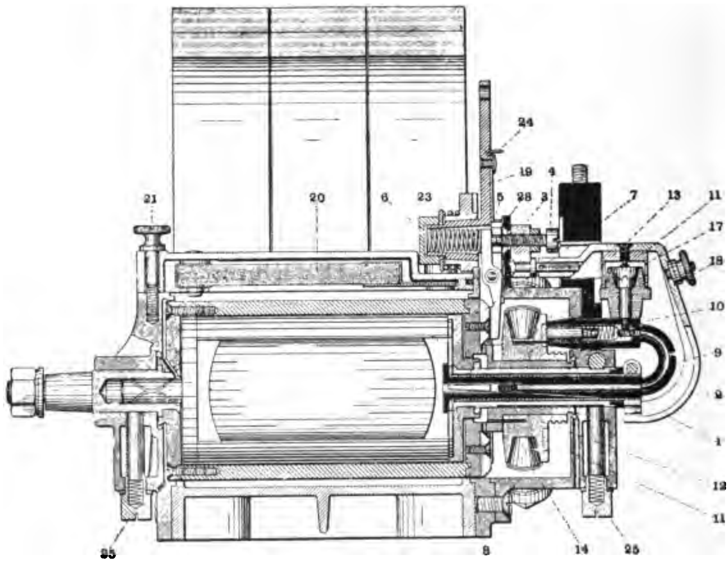


FIGURE 86—THE SIMS BOSCH MAGNETO.

ary current to the carbon brush 10. This brush conducts the current to the slip ring 11 of the distributing disc 12. The segment 13, which passes successively under each of the carbon collectors mounted in the carbon holders 14, and thereby connects these carbons with the end of the secondary winding, is electrically connected with the slip ring 11. Each of the carbon holders 14 is connected by brass rods with one of the small contact tubes of the conducting piece 15. The

plugs of the plug contact 16 are pushed into these small tubes, whilst the wires which form the connection with the ignition plugs of the various cylinders are screwed to their other ends. The secondary current flows successively through the secondary winding of the armature, the brass tube 8, the bent carbon holders 14, the conducting piece 15, the plug contact 16, the

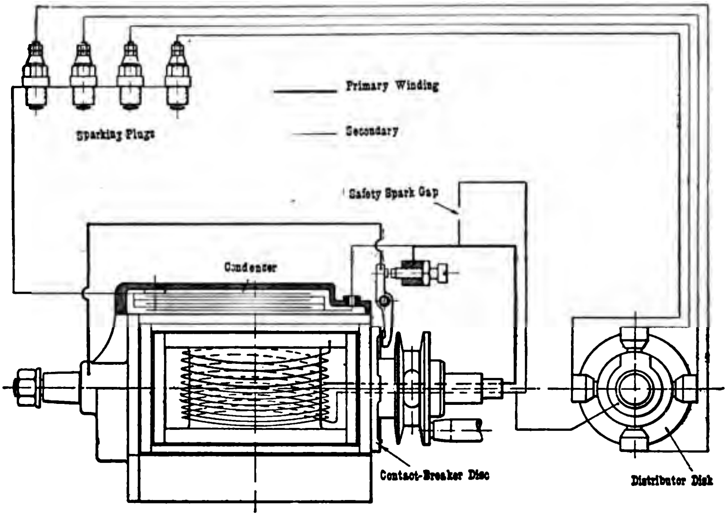


FIGURE 87.

wire leading to the ignition plug, and then returns to the body of the motor and the machine to the armature core, and then through the primary winding to its junction with the secondary winding.

The entire arrangement of the machine is diagrammatically illustrated in the figures (86) and (87).

THE WORKING OF THE MAGNETO. The working of the machine depends on the production of an alternating current in the armature winding by the

rotation of the sleeve. This current attains its maximum value when the sleeve has been rotated through an angle of 90 degrees. By the making and breaking of the primary circuit during the effective periods a current is generated in the secondary winding, the potential of which is so high that an arc-like spark is produced at the sparking plug, the insulated part of which is connected with one end of the secondary winding. The magneto machine is designed to produce four sparks per revolution; consequently, if attached to a four-cylinder motor, the machine must rotate at the same rate of speed as the cam shaft. As the distributor contact 13 is only in connection with one of the current collecting carbons when the contact is broken, the spark can only be produced in one cylinder at a time.

SAFETY SPARK GAP. To prevent the machine from being subjected to too high currents, when for some reason the connection between it and the sparking plug is interrupted whilst the machine is in motion, a safety gap 17 is placed in circuit between the bent carbon holder 9 and the conducting bar 2. This safety sparking gap, however, is only able to stand the discharge of the machine for a limited time, and great care must therefore be taken when dealing with motors having a double ignition system, that the discharges are not constantly passed across the safety sparking gap during the time the magneto ignition is not in use. Under these conditions it is absolutely necessary to cut out the magneto ignition altogether by short circuiting the primary current. For this purpose an insulated wire it attached to the conducting bar 2 by means of the nut 18, and conducted with an ordinary switch, the

second pole of which is connected with the body of the machine or with that of the motor. As soon as this switch is short circuited the sparking will cease.

TIMING THE IGNITION. For the purpose of adjusting the time of ignition the contact lever 5 is so mounted on the rotary lever 19 that the platinum contact of the lever 5, as well as the contact screw 4, lies accurately in the axis of rotation of the lever 19. By moving the lever 19 the position of the lower arm of the contact lever 5 is altered in relation to that of the disc 7, and consequently the deflection of this arm takes place, earlier or later in relation to the rotation of the sleeve. The sparking is not advantageously effected at early ignition, provided of course, that the breaking of the contact of the primary current is brought about at the beginning of the effective induction. At this moment the cylinder is just a few degrees past its horizontal or vertical position. When in this position the contact may be broken after the sleeve has been rotated through an angle of less than thirty degrees.

In order that the greatest possible benefit may be derived from this mode of sparking, it is necessary that the motor should be started with a rather early ignition.

SPEED AND DIRECTION OF ROTATION. It has already been stated, when describing the action of the machine, that the Bosch Arc Flame Magneto Machine produces a spark at each ninety degrees of rotation of the sleeve. The speed at which the sleeve of the machine is rotated by the motor varies according to the number of cylinders of the motor. If the motor has either two or four cylinders, it must be rotated at

the same speed as the cam shaft; if the number of cylinders is six, it must be rotated one and a half times as quickly, that is to say, it must have passed through ninety degrees whilst the cam shaft has passed through six degrees.

When ordering the machine it is necessary to state the number of cylinders of the motor for which it is intended, and also the direction of the rotation of the machine, and, if for a two-cylinder motor, the position of the cranks should be also stated. It is sufficient to state whether the machine is run to the right or to the left, that is to say, whether, viewed from its driven end, it is to rotate clockwise, or anti-clockwise.

THE REMY LOW TENSION MAGNETO SYSTEM.* The magneto generates two electrical impulses for each revolution of its armature at diametrically opposite points in the armature revolution. These impulses last for only a part of each half revolution, but are of sufficient length that sufficient current may be used from each impulse for ignition for from about 30 to 45 degrees of the armature revolution. The magneto, being gear driven, must therefore keep step with the engine, and the impulses generated by it coincide with the separation of the engine electrodes. Since at the times between the impulses in the revolution of magneto armature there is no current generated, it is evident that should gears be improperly set, so that impulses and separation of engine electrodes did not coincide, spark would not occur. The alternating current magneto must therefore always be gear or positively driven and properly timed. With the four-cylinder, four-cycle engine, the magneto is gear driven at the same speed as that of the engine crank shaft and may

*Reprinted from Remy Magneto catalogue.

be run in either direction. Gears are so set in installing magneto that the timing range of the engine electrodes coincides with the range of the electrical impulses of magneto. The range of the electrical impulses is marked upon the magneto, so that proper setting of gears is easily accomplished.

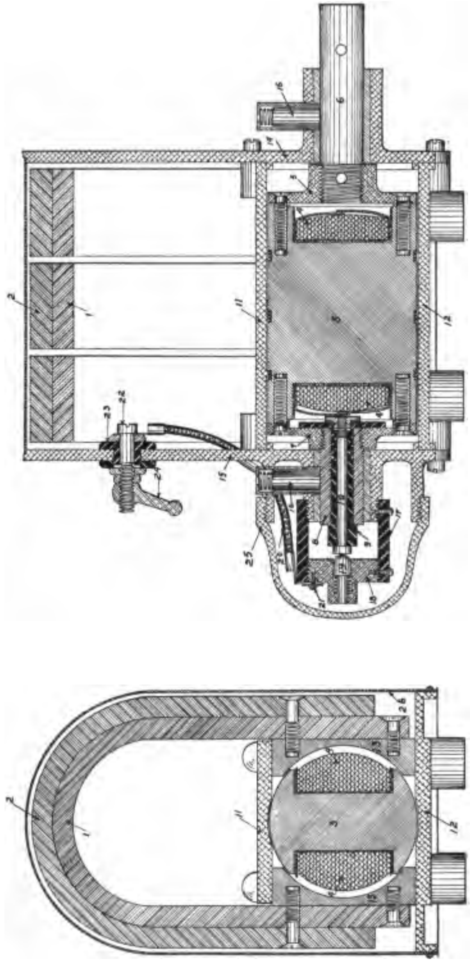


FIGURE 88.
TRANSVERSE AND LONGITUDINAL SECTION OF REMY LOW TENSION MAGNETO.

THE COOLING SYSTEM

THE COOLING SYSTEM. In the gas engine, instead of burning the fuel outside, and using some medium

FIGURE 89—RADIATOR WITH COILS OF SMALL TUBES.

FIGURE 90—RADIATOR WITH FAN.

to convey its heat into the cylinder of the engine, the combustile mixture is directly introduced into the work-

ing space behind the piston. Under these conditions it will be readily seen that the surrounding walls of the cylinder will become quickly heated, and if some method of cooling is not provided the friction caused by the unequal expansion would soon become so excessive as to stop the motor.

The temperature sometimes runs as high at 2500 degrees Fah. or higher and it is therefore necessary to design the combustion chamber so that its walls may be readily and quickly cooled to a reasonably low temperature. The process of cooling involves the transfer of heat from the warm body to a cooler one, and may be brought about directly or indirectly. Both the direct and indirect systems are used in automobile construction, the former being known as air cooled vehicles, the latter as water cooled cars.

AIR COOLED MOTOR. In the first case a blast of air is forced past the cylinder walls between fins, or any other cooling device which may have been added to increase the radiating surface. There are various types of these cooling devices, the simplest being the plain cast iron cylinder fitted with concentric cast iron or copper rings or flanges, which are embedded in the walls at the time of casting. Some use plain cylinders into whose walls are screwed short metal threaded rods, others use a similar construction substituting copper tubing drilled full of holes, and still others use flanges of aluminum, or other heat conducting metals. While the various methods of construction differ greatly yet the same result is sought, the rapid transfer of heat to the air, and the subsequent cooling of the metal walls.

The total amount of radiation surface on the cylinder

must be such that when a certain amount of air passes the surface per minute, enough heat will be removed to insure a proper working of the motor. Just what this temperature is, and just how many square inches of cooling surface are required for a particular cylinder are matters of different opinion among designers, and while it is possible to figure theoretically the area of cooling surface which will be required, yet it must be left to the experimental engineer to determine just what the car will do when put on the road.

THE ADVANTAGES OF AN AIR COOLED MOTOR.

First. There is no water system, no tank or radiator.

Second. Owing to the absence of all water jackets the weight of the motor will be considerably less.

Third. The car can be run without fear of freezing during the winter.

Fourth. It is not necessary to carry a water supply, and there are no pipe connections to leak.

THE DISADVANTAGES OF AN AIR COOLED MOTOR.

First. Cylinders sometimes become very hot, especially after the motor has been running under load on low speed.

Second. It is frequently necessary to use an excess of lubricating oil in order to overcome the friction which causes unequal expansion.

Third. Owing to the high temperature it is necessary to regrind the valves often.

Fourth. The whole motor is more sensitive, and requires careful watching and frequent adjustment.

WATER COOLING. When the indirect method of cooling is used, instead of using air, some cooling liquid, such as water, or oil is circulated through jackets built around the cylinders, and later forced into

the radiator in the front of the car where it gives up its heat to the air.

Fig. 91 shows the diagram of such a system. You note that the radiator froms a source of supply. The water is driven by means of a pump from the bottom of the radiator, and forced into the bottom of the cylin-

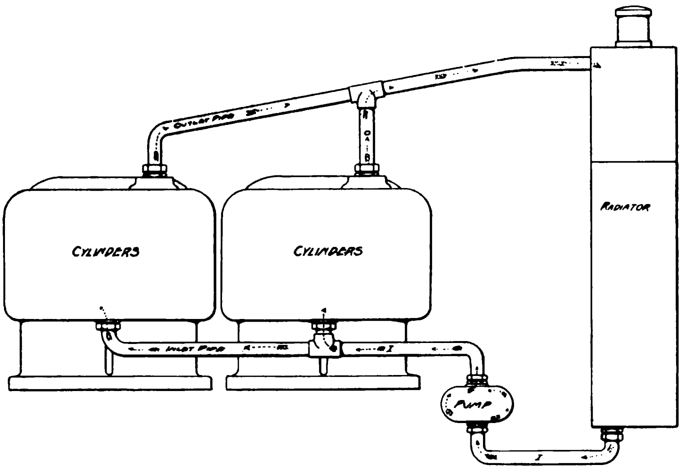


FIGURE 91—SHOWING WATER COOLING SYSTEM.

der water jackets, where it rapidly absorbs the heat from the metal walls, and rises to the top from which it passes again to the radiator. Here it is circulated through a set of tubes having a large amount of radiating surface, and rapidly cooled by means of the air which passes through the radiator.

RADIATORS. Radiators vary in their construction, some manufacturers using round tubes fitted with circular or squared fins, some use a cellular construction and still others a combination of the two. The main tubes are generally made of copper or brass and the

fins of copper or tin. The shape of the radiator is determined by its position on the car, and the general design of the body. Various shapes are shown in the

FIGURE 92-93—TYPICAL RADIATORS.

illustration. In some types the circulation is through horizontal tubes, in others is through vertical tubes, and in some it is made to pursue a devious course. Everything possible is done to increase the cooling

power of the radiator, and all manufacturers are now coating the entire surface with lamp black, as this has been found to give excellent results. In addition to this, all up-to-date makers have provided the cylinders with pet cocks, so that they may be drained easily, overflow pipes, and expansion chambers, and have worked out their designs in such a way that no steam pockets or air spaces can be formed.

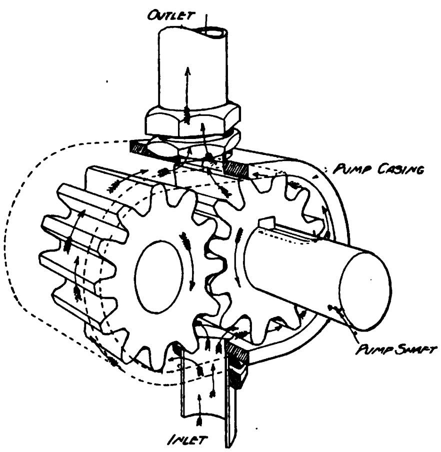


FIGURE 94—SECTION OF PUMP.

THE WATER PUMP. Water pumps, like radiators, are made in many different styles, some of the rotary variety, some centrifugal, fitted with paddles like a water wheel, and others, known as gear pumps, simply two gears which run together inside of a casing. This latter type is becoming very popular, and is used now on many of the modern cars. Fig. 94 shows a section of such a pump. You note that the water enters at the bottom and is forced around on the outside of the

gears. As the cogs are always in mesh it is impossible for the water to travel back again, and consequently a steady flow is the result. This type of pump is very easily operated, being driven from the engine itself, and is positive in its action. It should, however, on account of its construction, be kept carefully lubricated, and not allowed to wear.

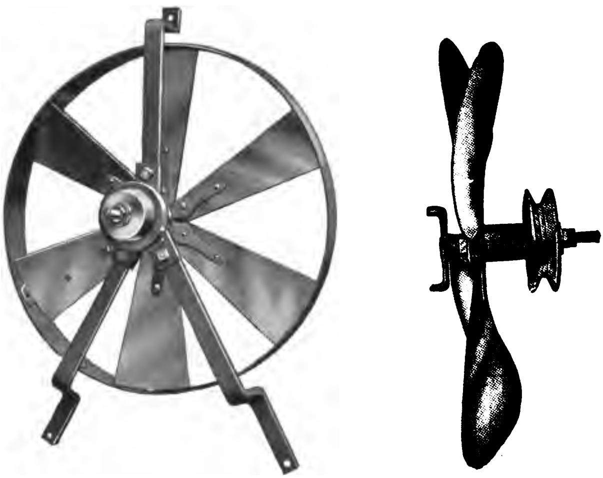


FIGURE 95—TYPICAL FANS.

THERMAL CIRCULATION. It is possible, if the system is laid out properly, to circulate the water without the aid of a pump. This is due to the fact that water when heated rises, and consequently, if all the passages are free, a thermal circulation will be set up which will continue as long as the walls of the motor remain hot. In passing through the radiator the cold water naturally has a tendency to go to the lower level, and, therefore, the coldest water is at the bottom of the radiator where it should be. In other words, the sys-

tem works exactly like the hot water heating system in a house.

THE PIPING. Nearly all of the piping used in a water system should be tubing if possible, because it is much more satisfactory than hose, and less liable to leak. There is one place, however, where it is almost absolutely necessary to use hose, and that is for the radiator connections. Owing to the vibration of the car, it is almost impossible to maintain a good joint if tubing is used throughout. If the two radiator joints are made with steam hose the vibration of the radiator will not seriously affect the connections.

FIGURE 96—TYPICAL RADIATOR FINS.

ANTI-FREEZING MIXTURES. During the winter months when the temperature is very low, it is necessary to introduce into the cooling system some mixture which will prevent the water freezing. Various formulas are used, three of which are given below:

No. 1.

Glycerine,	49 per cent.
Sodium Carbonate	2 per cent.
Water,	49 per cent.

No. 2.

Glycerine,	50 per cent.
Water,	50 per cent.

No. 3.

Alcohol,	35 per cent.
Water,	65 per cent.

After removing the anti-freezing mixture in the spring, the radiator should be carefully cleaned, owing to the fact that deposits are very often formed in the system which will interfere with the circulation.

CARE OF SYSTEM. The cooling system is a very important part of a gasoline motor, and should be regularly inspected. Care should be taken that the radiator is kept nearly full, that all connections are tight, all piping free, and all moving parts of the pump well lubricated. The cooling surface of the radiator should be kept free of mud, as it tends to reduce the efficiency of the radiator. If the water is at all muddy, it should be carefully strained in order to prevent any sand or sediment from entering the system.

THE TRANSMISSION GEAR

The term "transmission gear" has come to mean only that portion of the transmission gearing proper which lies between the engine shaft and the propeller shaft or driving chain, and does not include the rest of the driving gear, such as the bevel gear, jack shaft or differential. In this article, therefore, we will confine

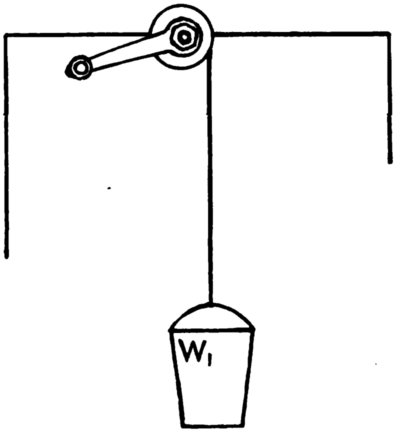


FIGURE 97.

ourselves to a study of the transmission in its more restricted sense.

What is the transmission, and why is it a necessary part of the gasoline motor car?

In the first place the piston of a gas engine is worked upon by an intermittent force, and not, as in the case in a steam engine, by a continuous pressure. A gas engine running at high speed, however, produces a fairly uniform turning effect so that after a gas engine gets under way it makes an equally good driving power.

One of the first objects, therefore, of a transmission is to allow the engine to speed up until the energy which is stored up in the fly wheel is sufficient to keep the shaft revolving at a speed showing no great percentage of variation.

Secondly, a transmission is necessary when the engine is required to work under a very heavy load which under other circumstances would cause the motor to

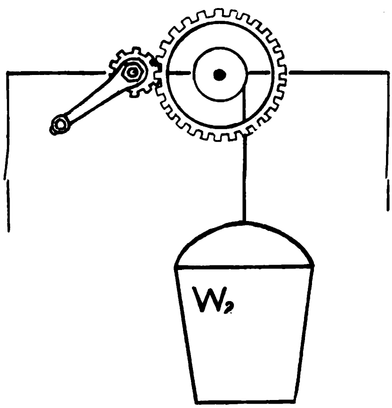
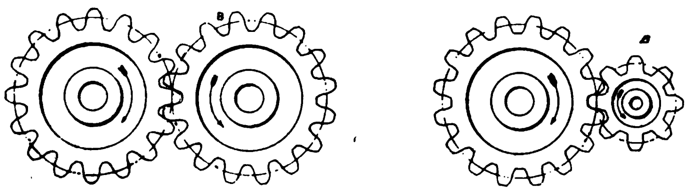


FIGURE 98.

slow down, and stall if required to work under such conditions any great length of time. In other words, to use a homely example, suppose a man was pulling up a bucket in the well by winding a rope around the drum of a windlass, that the bucket must be raised to a certain number of feet every minute; then if we assume that the bucket of water weighed such an amount as to require all his strength to fulfill these conditions, and that any extra weight added to the bucket would overtax his strength to such an extent as to make further progress impossible, you can see that some mechanical contrivance is necessary which

will enable him to exert the same strength but apply it through a longer period of time. To make this plain, suppose that he wished to lift a barrel weighing 600 pounds up to some point ten feet above him. This you would realize would be impossible. If, however, he should build an incline long enough he would be able to roll it up, accomplishing the same work, but it would take him a longer time to do it. Another way of accomplishing the same object would be by the use of a lever. Now, to revert to our former illustration, suppose that instead of turning the drum of the windlass by a crank,



A FIGURE 99. B

IN FIGURE "A" BOTH WHEELS ARE SAME DIAMETER AND HENCE RUN AT SAME SPEED. IN FIGURE "B" THE LEFT GEAR IS ONLY ONE-HALF DIAMETER OF OTHER GEAR, HENCE ITS SHAFT RUNS AT TWICE THE SPEED.

he puts a gear on the end of the drum, and then attaches the crank to a smaller gear which meshes with the larger gear. Let us assume for the sake of argument that the large gear on the windlass hub is six times the diameter of the gear to which the crank is attached. Then, in order to turn the large gear around once it will require six revolutions of the small gear, and the pressure exerted will be only one-sixth of that required if the crank was fastened to the larger gear direct. Thus you see that by introducing this set of gearing the work may be done, the time taken, however, will be six times the former amount, but only one-sixth the effort required.

Now, let us compare this with the work done by the engine of an automobile in driving the vehicle by turning the rear wheels. The engine in this comparison represents the man, and the force required to drive the machine represents the work required to lift the bucket. Then to make the case plain suppose we assume that the engine shaft runs across the car and that the general arrangement of the other parts of the driving mechanism is like that shown in the illustration. You

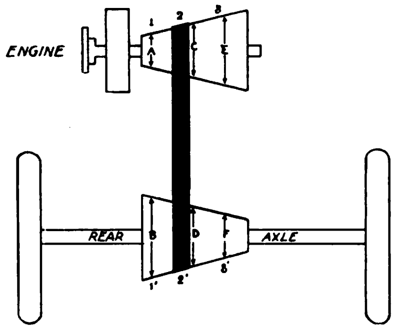


FIGURE 100.

will see that if two cone pulleys, one on the engine shaft, and one on the rear axle, are connected by a belt so that the speed of the rear axle may be varied by shifting the belt from one side to the other; that is, if the belt is started on the left side of the pulleys where the diameter A is one-third the diameter B the rear axle will revolve once for every three revolutions of the engine; likewise when the belt is in position 2 where diameter C is equal to diameter D then the engine and the rear axle will revolve at the same rate. Position 3, where the diameter E is three times diameter F, the engine shaft will revolve at only one-third the rate of the rear axle. In position 2 we have the

example of the man winding up the bucket with the crank fastened direct to the windlass hub, while in case 1 we have the power applied through what corresponds to the set of gearing, the engine running at the same rate of speed as in case 2, but transferring three times the power to the axle which, however, runs at only one-third the rate of speed. Of course, this type of transmission is never used in automobile practice,

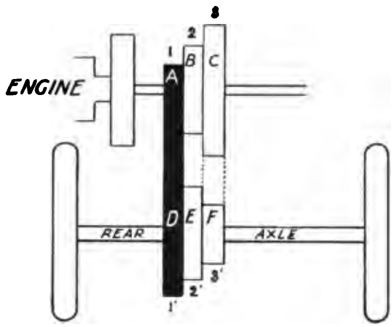


FIGURE 101.

a double cone type based on the same principle is in use on a foreign car.

In order to make the principle of a transmission even plainer, suppose we take the example of an ordinary belt transmission. Instead of mounting cones upon the engine shaft or rear axle let us use a set of step pulleys; then if we consider that the arrangement is similar to that shown in Fig. 101 you can see that by shifting the belt into positions 1, 2 and 3 three different speeds will be obtained, and a reverse direction of rotation could be produced by twisting the belt or taking off the belt entirely and introducing a wheel in between any two sets of gears. Now, to carry the com-

parison one step further, suppose it were possible to take off the belt and move the two shafts toward each other until wheel A rubs against wheel D; this, of course, would not be possible unless B and E and C and F were in contact. Let us assume for the instant, how-

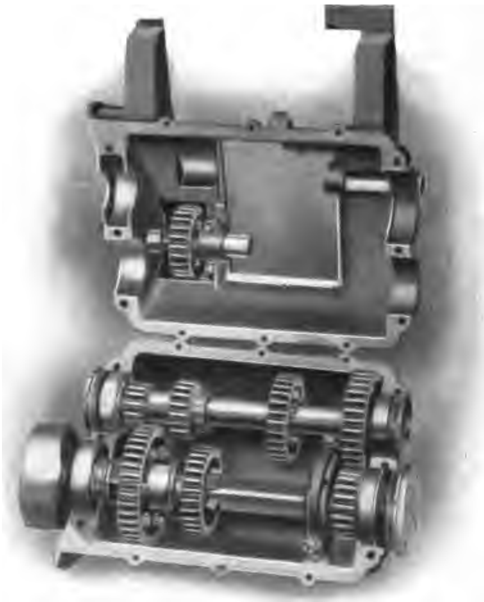


FIGURE 102.
A SLIDING GEAR TRANSMISSION SHOWING MOUNTING OF GEARS AND FORM OF CASE.

ever, that we can move one wheel without moving the other two, then you will see that the power will be transmitted from wheel A to the rear axle through wheel D; or if we assume that B and E are in contact, and A and D, and C and F are not, then the transmission of power will be through wheels B and E and the ratio between the engine shaft and rear axle speed

REVERSE SPEED.

SLOW SPEED.

INTERMEDIATE SPEED.

HIGH SPEED—NO GEARS IN MESH.

FIGURE 103.

CUTS OF A WELL-KNOWN TRANSMISSION SHOWING POSITION OF GEARS AT DIFFERENT SPEEDS.

will be proportional to the diameter of the wheels in contact. In other words, if D was three times the diameter of A and the rear axle would only turn one-half as fast as the engine shaft, while if B and E were in contact, the diameters of these two wheels being the same, the rear axle would run at the same speed as the main shaft. If these conditions are true the same would hold good if gears were used, because gears are nothing more nor less than rollers equipped with teeth which prevent slipping, therefore, in order to build a transmission all that is necessary for us to do is to separate the wheels and arrange them so that different sets may be brought into mesh separately. There are several ways of doing this, but the two best known types are the individual clutch transmission and the sliding gear, both of which are shown in the illustrations.

THE INDIVIDUAL CLUTCH SYSTEM. The illustration shows a well-known type of this transmission, as well as the bevel gear and differential which is used in connection with it. It has three speeds forward, and one reverse. The power, you will notice, come in from the fly wheel through a clutch which transfers it to the shaft carrying the smaller gears. Each of these gears is fastened to this shaft and revolve with it; the four larger gears, three of which are in mesh at all times, run idle on the bevel gear shaft, but can be separately caused to revolve with it by tightening up the clutch inside of the rim of a gear. A set of levers are provided for accomplishing this object, and are easily operated by means of one or two control levers. The reverse is obtained by shifting the lower right hand gear so it will mesh with another gear, which in

with the first small gear on the upper arrangement is very simple and has sev- of advantage, such as freedom from shocks nge of speed, ease of manipulation, abso- ossibility of having more than one set of esh at once, it being impossible to put in a

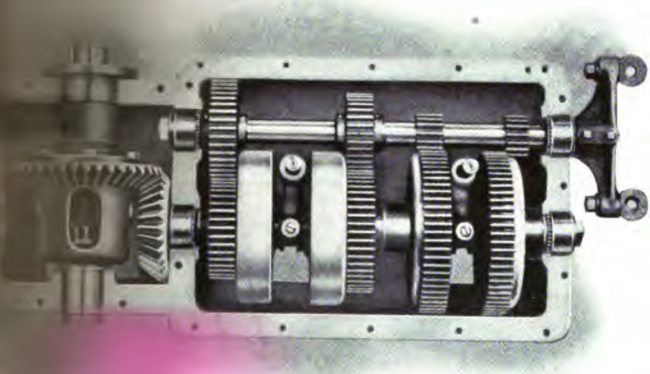


FIGURE 104.

SYSTEM—THREE SPEEDS FORWARD AND ONE REVERSE. ATION TRANSMISSION AND BEVEL GEAR CASE.

ntil the one previously engaged has the neutral point.

SPEED PROGRESSIVE SYSTEM. In the progressive system we have the same of shafts, but the power goes in at P and T, instead of going in on one shaft and another, as is the case in the individual n. The shaft T is squared for a portion , and runs in a bearing inside of the gear

C. The gears I and L are cut out of the same piece of metal, and fitted with a square hole so that they can be slid along the shaft P and yet cannot revolve independently of it. The gears C1, I1 and L1 are fastened rigidly to the counter-shaft C-S, therefore revolves with it. The gear R is an "idler," but is so

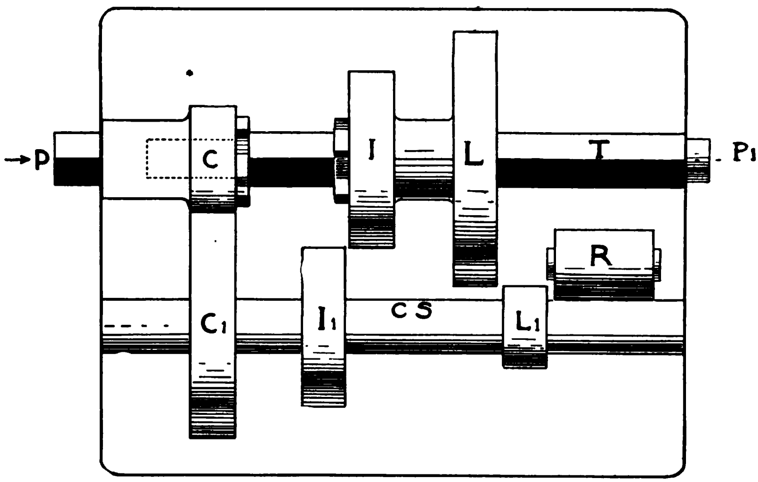


FIGURE 105—THREE-SPEED PROGRESSIVE SYSTEM.

mounted that it may be shifted into mesh with L and L1, when it is desired to obtain a reverse.

Now let us see how the various speeds are obtained. We will assume at first that none of the gears are in mesh except C and C1, and that no power is being transmitted to the rear axle; then in order to obtain the low speed we will shift the gear combination I L so that the gear L will be in mesh with L1. The drive will then be through C, C1, L1, L, and out through the shaft T to axle. For the intermediate speed the

gears will be shifted so that I will be in mesh with I1, L, of course, being moved out of mesh with L1. The drive will then be through C, C1, I1, and out through the shaft T to the rear axle. For the reverse L and R will be shifted so that L meshes with R, and R with L1. The drive will then be through C, C1, L1 R, L. The introduction of the fifty gear causing a reverse direction of rotation of the rear axle. For the highest speed gears I and L are moved to the left so that they will be in mesh with no other gears, but a clutch cut into the left side of I will fit into the corresponding clutch in the gear C. This serves the purpose of coupling the shaft T to the shaft P, and the drive will be direct.

This form of transmission although satisfactory in performance is not used very extensively on account of the excessive lengths of shafts and correspondingly larger cases and bearings which must be used. The one sliding member prohibits selective control, and this, coupled with the fact that the weight of the various parts is rather excessive, has resulted in the adoption by most motor car builders of a slightly modified type of sliding gear called the selective system.

THE THREE SPEED SELECTIVE SYSTEM. This gearing consists of two parallel shafts, T and CS, the counter-shaft CS having keyed to it the gears C1, I1, L1 and R1, the latter a squared shaft T carrying the gears I and L. Gear G is an "idler" used for obtaining the reverse. P is a driving shaft directly connected with the engine through the clutch. Its gear C runs free on the shaft T, and is in mesh with gear C1. Taking first the low speed position, we note that the drive is from C to C1, to L through L1. On the inter-

mediate speed, L is thrown out, and I is thrown into mesh with I1. For high speed the claw clutch on I is slid into mesh with a corresponding clutch on C. The drive in this case is "direct," going from P directly out through T, the gears C and I being locked by the

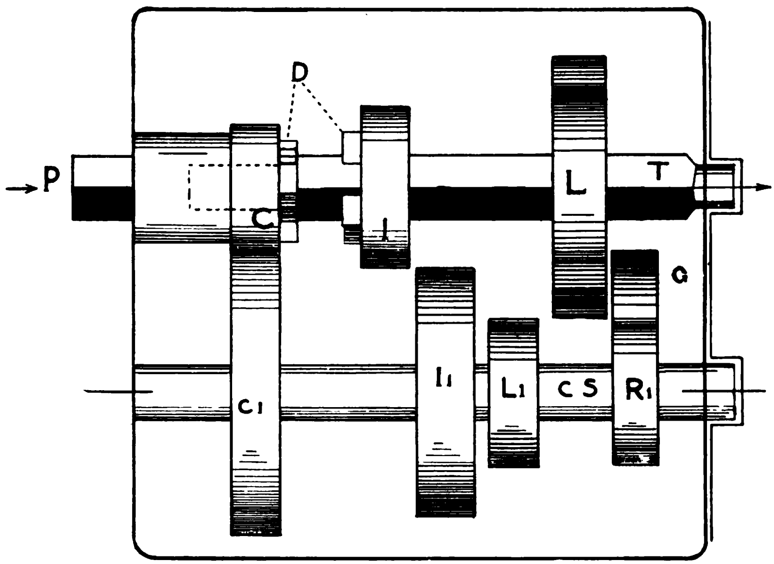


FIGURE 106—SHOWING ONE FORM OF THE THREE-SPEED SELECTIVE SLIDING GEAR.

clutch. For the reverse, the gears R1, G and L are in mesh, and as G makes the fifth gear in the system, the direction of rotation is reversed. The gears are shifted by means of one control lever, which is placed within easy reach of the driver. Another three-speed selective control system is here shown. This gearing consists of two parallel shafts, I and S, the former having keyed to it the gears B, C, D, and E, the latter,

a "squared" shaft for carrying the gears H and F. Gear G is an "idler," used for obtaining the reverse. S is a driving shaft directly connected with the engine through the clutch. A runs free on the shaft S, and

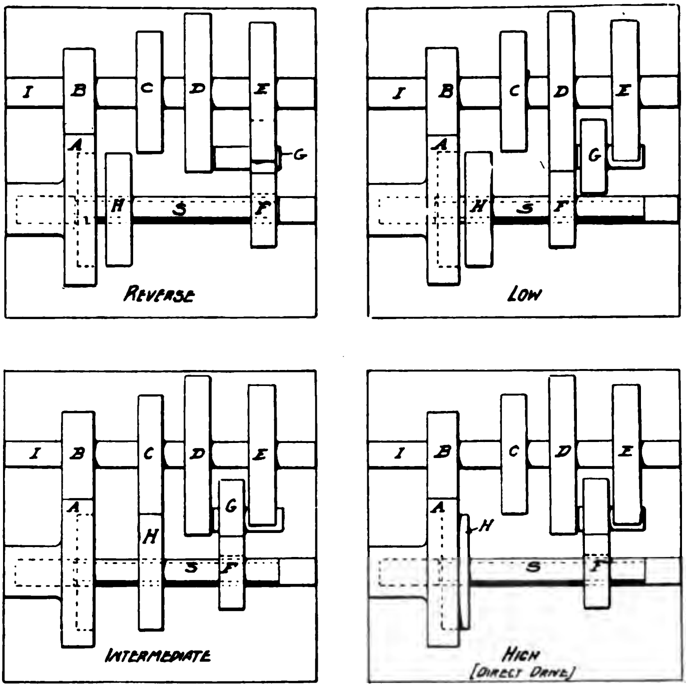


FIGURE 107.

A THREE-SPEED SELECTIVE SLIDING GEAR—DIAGRAM SHOWING POSITIONS OF GEAR AT VARIOUS SPEEDS. IN THIS CASE AN INTERNAL GEAR CUT IN RIM OF "A" SERVES AS A CLUTCH.

is in mesh with gear B. Taking first the low speed position, we note that the drive is from F to D to A through B. On the intermediate speed, F is thrown out, and H is thrown into mesh with C. For high speed, the gear H is slid into mesh with an internal gear cut into the rim of A. The drive in this case is

"direct," going from S directly out through A, the gear H simply serving as a clutch. For the reverse, the gears E, G, and F are in mesh, and as G makes the fifth gear in the system, the direction of rotation is reversed. In this form of transmission the gears are so arranged that any speed may be obtained with-

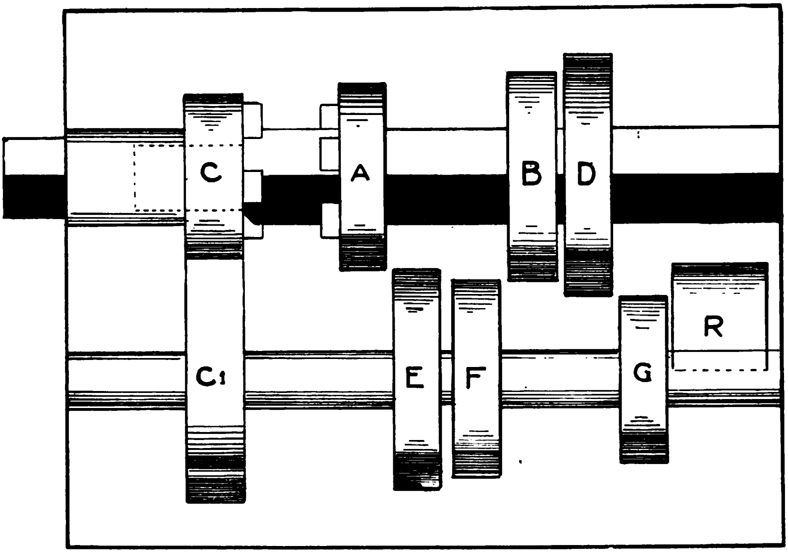


FIGURE 108—THE FOUR-SPEED SELECTIVE TYPE.

out having to go through any of the others, and, therefore, the one lever selective control may be very easily used. This feature is appreciated by everyone, because it makes the operation of changing gears very simple, and allows the car to be easily handled on crowded streets and on difficult grades.

THE FOUR SPEED SELECTIVE SYSTEM. The four speed selective transmission differs from the three

speed only in the fact that four gears are used on the driving shaft instead of three, the various gears being brought into mesh as shown in the illustration. In the case of a low speed, the drive is through C, C1, G and D. The second speed through C, C1, F and B. Third, through C, C1, E and A. For the reverse, the reverse

FIGURE 109—A CONE CLUTCH.

gear R is thrown into mesh with G and D making the drive through C C1, G R and D.

The various systems used in modern cars are all based on the same principle but differ in minor details; according to the ideas of their designers. All of them are enclosed in an oil-tight case and run in a bath of oil. The shifting mechanism also differs, but if you will examine all of them carefully you will note that the same result is obtained, and it is only on account

of various patents which cover these devices that transmissions are not more uniform.

CLUTCHES. In order to allow the engine to run when the car is standing still, and to provide a suitable means of connection and disconnection between the engine and transmission, for better controlling the

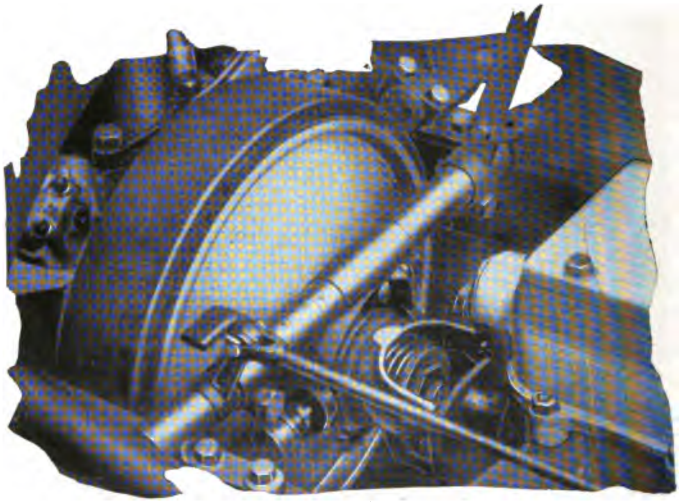


FIGURE 110.
EXTERNAL VIEW OF A CONE CLUTCH SHOWING SPRING WHICH HOLDS CLUTCH IN PLACE AND OTHER MECHANISM FOR OPERATING IT.

car, a piece of mechanism called a clutch is used. It is nearly always some form of friction device. There are numerous types, each deriving its name from its form or its method of engagement. The simplest type is that known as the "dishpan" or cone type, which is shown in one of the illustrations. It consists of a portion of a cone, the outside face of which is covered with leather. It is so mounted that it may be made to fit into an internal cone cut into the rim of the fly

wheel. Such a clutch is held in place by a very stiff spring which maintains a contact between the friction surfaces until it is disengaged by a movement of a foot lever or the emergency brake lever to which it is connected. Internal expanding clutches are also used similar to the one shown in Fig. 111. Other well known types are those known as "external contracting," "multiple disc," "hydraulic" and "magnetic"

FIGURE 111—INTERNAL EXPANDING CLUTCH.

clutches. The planetary transmission clutch arrangements differ somewhat from those used in connection with the sliding gear and individual clutch, but they accomplish the same result and when once examined will be easily understood.

PLANETARY TRANSMISSION. Planetary transmission so called on account of the "sun and planet" arrangement of the driving gear and pinions is, while easiest to operate, the most difficult to understand. The planetary gears may be divided into two classes,

one known as the "internal" gear type, the other as the "all spur" gear system. The explanation of the operation of either of these forms is difficult even if one has the working models before him, and the author will, therefore, not attempt to go into details of the subject. To those who are desirous of obtaining further information regarding this type of transmis-

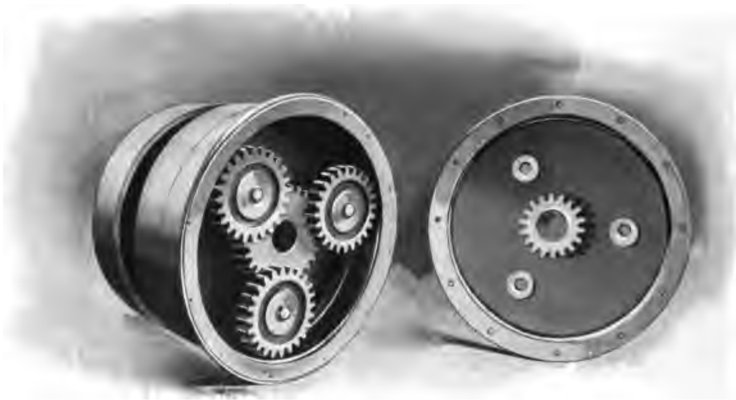


FIGURE 112.
A TWO-SPEED AND REVERSE PLANETARY GEAR.

sion gear the following books may be recommended: Elements of Mechanism by T. M. Goodeve, page 222; International Library of Technology, page 887, applied mechanics; Homan's Self Propelled Vehicles, transmission gears; and other books on mechanics and gearing.

The planetary transmission is especially adapted to the runabout type of motor car, and used in this connection is simply supplied with three speeds, one reverse and two forward, the latter having a direct

drive on high speed. Some of the makers are using a three speed forward and reverse with success in large touring cars, but this type has not yet met with universal acceptance.

THE FRICTION DRIVE. One of the most novel transmission devices, and one which has been used with some degree of success, is that known as the "friction

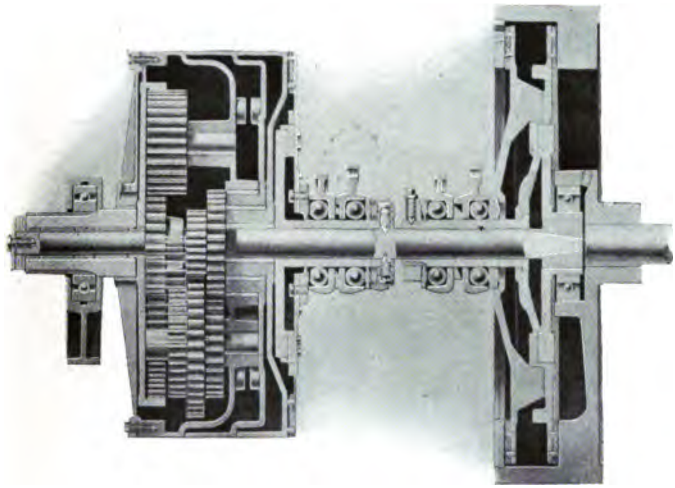


FIGURE 113.
A THREE-SPEED AND REVERSE PLANETARY GEAR.

drive." By its use the system of gears is done away with entirely, and practically the same result secured by the use of only two component parts, which are a flat revolving plate, and a friction wheel placed at right angles to it.

This friction wheel is mounted on a feathered shaft, and is capable of being moved from one side of the disk across to the other, allowing the driving diameter of the disk, and consequently the speed ratio, to be

varied at will by a movement of the control lever. The feathered shaft to which the friction pulley is attached is connected by means of a chain or bevel gear to the rear axle. A study of the illustrations will make the operation plain.

While the friction type of drive has its advantages as regards changes in speed, yet it also possesses disadvantages, such as loss of power by slippage, difficulty of producing proper friction surfaces, and difficulty

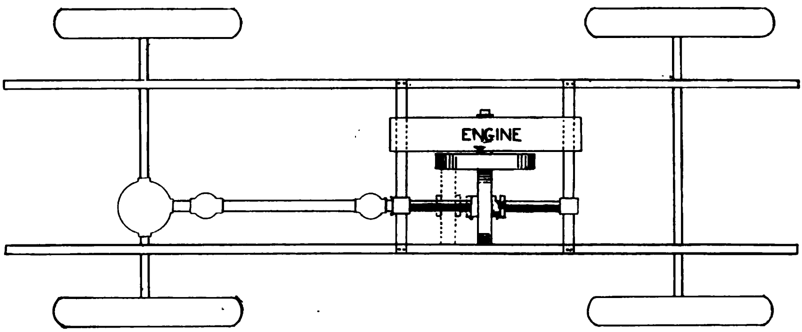


FIGURE 114.
CHASSIS DIAGRAM OF FRICTION DRIVE.

of adjustment, which have not as yet been sufficiently overcome to warrant its universal use.

THE SINGLE CHAIN DRIVE. The methods of transferring the power from the transmission shaft to the rear axle vary according to the design of the machine and the location of the motor. In cars of the runabout type, where the crank shaft is parallel to the rear axle, the single chain drive is used, one sprocket being placed on the transmission shaft and another larger one surrounding the differential case on the rear axle. The two sprockets are connected by a chain. This

chain and sprocket system has been used on bicycles for a number of years, and will therefore need no explanation.

The sprocket ratio, which determines the relative speeds of the transmission shaft and rear axle may be easily calculated by counting the teeth on the respective sprockets. For instance, if the transmission sprocket

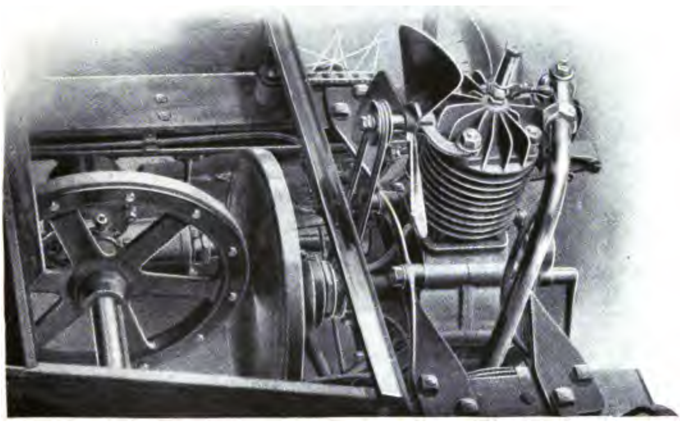


FIGURE 115.
A TYPICAL FRICTION DRIVE MECHANISM.

has ten teeth, and the rear axle thirty the ratio will be 10 to 30, or 1 to 3; that is the rear axle will run at only 1-3 the speed of the transmission shaft.

RADIUS RODS. When the spring construction is such that a depression or its resulting re-action is apt to produce a change in the chain length, or in other words, lengthen or shorten the distance between sprocket centers, steel rods are introduced, so fastened at the rear axle and a point on the frame that this distance will always remain constant, and not be changed

by the spring action. Such rods are known as radius rods.

FORMS OF CHAIN. There are various forms of chains used for driving purposes, some of which are

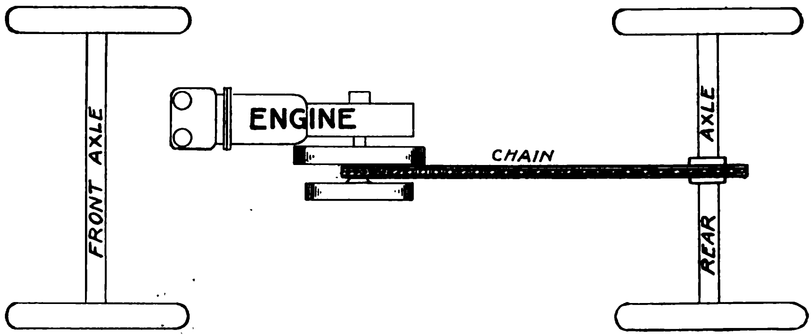


FIGURE 116—SINGLE CHAIN DRIVE.

shown in the illustration. The two most common are the roller and block types.

FIGURE 117—A ROLLER CHAIN.

ADVANTAGES OF THE CHAIN DRIVE. Owing to its simplicity the chain drive possesses many advantages, especially for light cars or machines, which are to be used in sections of the country where it is impossible to replace gears.

First. Each chain is provided with what is known as a "master link," at which the chain may be disconnected, or is so constructed that it may be taken apart at any point. For this reason repairs or replacements of links may be made almost anywhere and in a very short time.

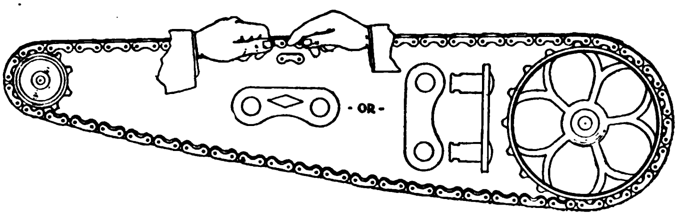


FIGURE 118—CUT SHOWING METHOD OF REPAIRING CHAIN AND "MASTER LINK."

Second. Chains and sprockets are open to inspection, and may be examined at any time.

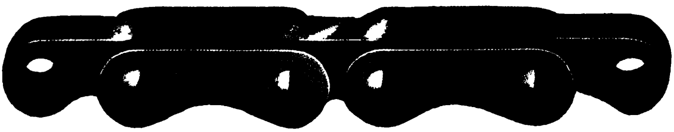


FIGURE 119—A BLOCK CHAIN.

DISADVANTAGES. The single chain drive, on the other hand, has several disadvantages. It is unprotected, and therefore, accumulates considerable sand and dust, which acts as an abrasive substance, and therefore causes wear.

Second. The chain gradually stretches and frequent adjustment is necessary in order to make it an efficient driving device.

Third. It is noisy to operate, and is very apt to pick up brush or wire lying in the road, thereby causing serious complications.

FIGURE 120.
ARRANGEMENTS SHOWING COMBINATION OF GEAR AND BEVEL—ONLY ONE CASE USED.

THE BEVEL GEAR DRIVE. Most of you, no doubt, are familiar with the chainless bicycle, and recognize in it the use of the bevel gear as a substitute for the

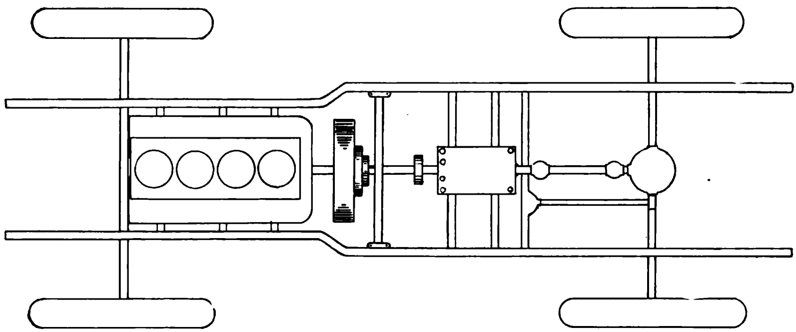


FIGURE 121.
CHASSIS DIAGRAM SHOWING THE BEVEL GEAR DRIVE.

chain. In the automobile a similar driving mechanism is used, the larger bevel being fastened to the differen-

tial case, the small bevel pinion being in mesh with it at right angles with the rear axle or countershaft. A glance at some of the illustrations will show you how these gears are made and located.

The gear ratio, as in the case of any other set of gears, may be determined by counting the number of teeth on each gear, the common ratios being 2½ to 1, 3 1-7 to 1, and 3½ to 1.

FIGURE 122.

A BEVEL GEAR DRIVE. CUT ALSO SHOWS DIFFERENTIAL GEARING.

THE CARDAN SHAFT. In nearly all cars you will notice that the rear axle is slightly below the transmission shaft, and that also the movement of the springs when the vehicle is passing over the road changes the position of the rear axle in relation to the transmission shaft. For this reason it is not possible to use a solid shaft to connect the transmission shaft with the bevel gear pinion. A shaft equipped with two flexible joints, known as universal joints, so-called on account of their ability to transmit power

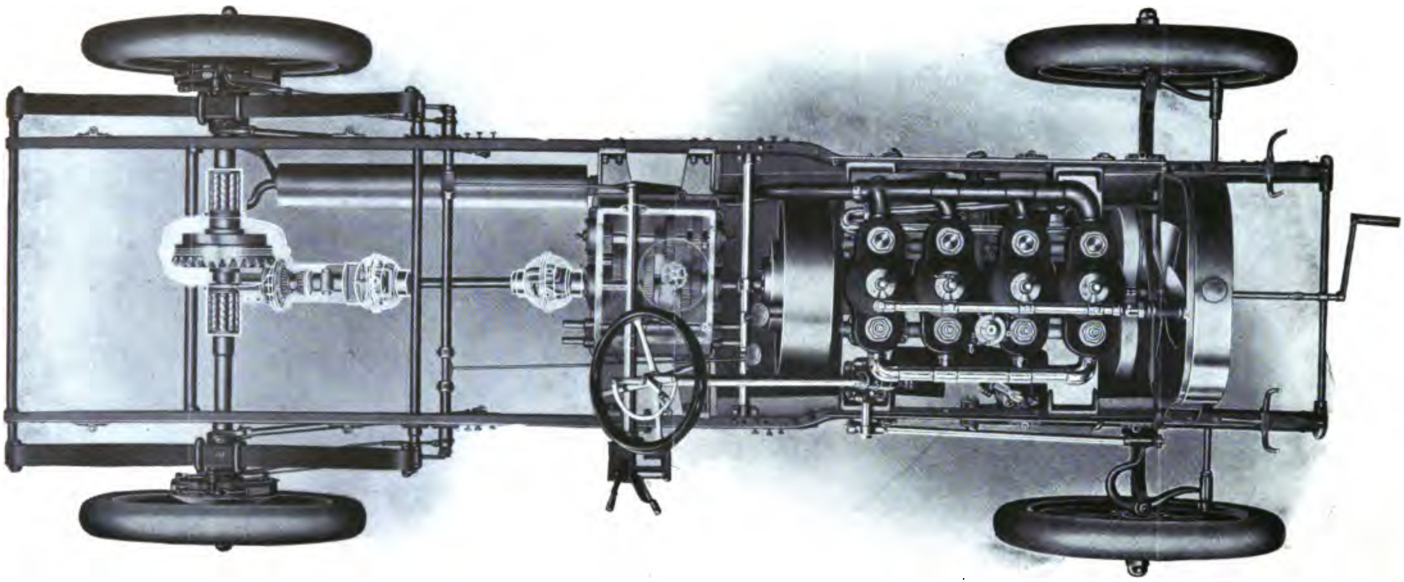


FIGURE 123.

A TYPICAL CHASSIS SHOWING USUAL LOCATION AND FUNCTION OF VARIOUS MEMBERS OF THE DRIVING SYSTEM. NOTE ALSO THE BEARINGS ON REAR AXLE.

from shafts running at an angle to each other, are used. Sometimes when it is desired to build the transmission and bevel gear so that they may be included in the same case this "propeller shaft" or "Cardan shaft" is placed between the engine and transmission instead of between the transmission and bevel gear.

FIGURE 124.
A "UNIVERSAL JOINT" AND THE STEEL CASING WHICH IS FITTED AROUND IT FOR PROTECTION AND BETTER LUBRICATION.

You will note that in two or three of the illustrations this type of design has been followed.

THE ADVANTAGES OF THE BEVEL GEAR DRIVE. When this form of driving mechanism is used the entire system may be completely enclosed in an oil tight case, the gears running in oil, the protective casing allowing no dirt or grit to interfere with the action of the gears. The bearings, too, no matter whether balls or rollers are used, may be easily kept lubricated,

and free from any abrasive substances, which would cut or destroy them.

THE TORSION ROD. In driving the rear axle by a bevel gear there is always a tendency for the axle to turn on its axis, and in order to prevent this action a rod fastened to the axle at one end, and equipped with a ball resting in a ball and socket joint at the other

FIGURE 125.

CUT SHOWING TRANSMISSION, DIFFERENTIAL AND TRANSMISSION SHIFTING MECHANISM WHEN USED IN CONNECTION WITH COUNTER SHAFT AND SIDE CHAIN DRIVE.

end, must be used. This rod is known as the torsion rod, so called because it prevents the axle from twisting out of its proper position.

THE COUNTERSHAFT AND SIDE CHAIN DRIVE. Sometimes in the case of cars having an exceedingly long wheel base, or for the purpose of working out a special design of running gear, a combination system of chain and bevel gear transmission is used. That is, the "countershaft," or "jack shaft," as it is often

called, is hung at some point on the frame between the engine and rear axle. This countershaft is constructed in very much the same manner as a bevel gear rear axle except that instead of placing the wheels at the two ends, sprockets are used instead. The rear axle is made solid, the same as an ordinary horse-drawn vehicle, and the wheels which run loose are equipped with sprockets connected with the countershaft sprockets by two side chains. This form of con-

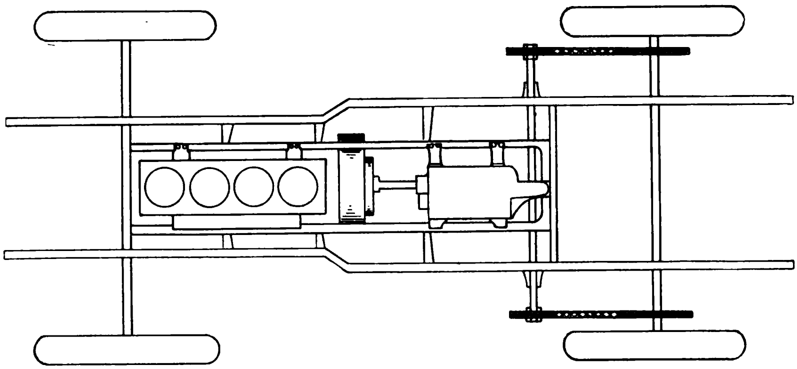


FIGURE 126.
CHASSIS DIAGRAM SHOWING COUNTERSHAFT AND SIDE CHAIN DRIVE.

struction is especially adapted to long wheel base trucks where the plain chain drive or bevel gear drive could not be very well used on account of the excessive distance between the transmission and rear axle.

THE DIFFERENTIAL GEAR. Perhaps one of the least understood and at the same time one of the most necessary parts of a self-propelled vehicle is the "differential" or "compensating gear," which is used on the rear axle or countershaft, as the case may be, for taking care of the varying speeds at which the rear wheels must run in turning a corner or in any way

changing the direction of the vehicle from one straight line to another. Those of you who have watched a military company go through their evolutions have noticed that whenever the line of men change the direction of their march it is necessary for the men on the inside to slow up or mark time while the rest of the

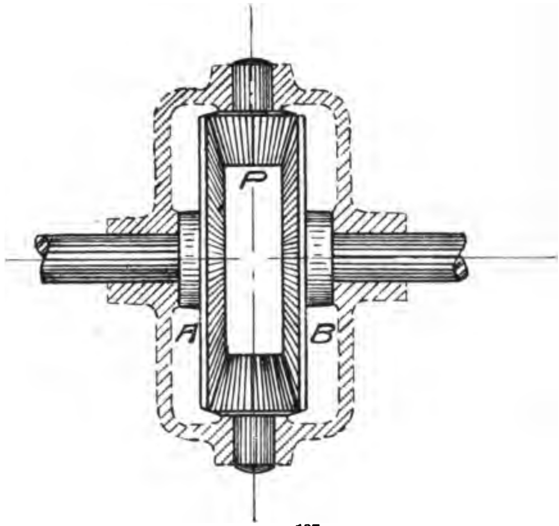


FIGURE 127.

DIAGRAMMATIC SKETCH OF BEVEL GEAR DIFFERENTIAL.

line comes around into position. This same thing happens when a vehicle turns a corner. The inside wheel traveling around a circle having a smaller circumference must slow up, and the outside wheel, owing to the fact that it must travel a larger circumference at the same time, is required to move more rapidly. Motor car manufacturers, therefore, found it necessary to divide the rear axle at some point between the wheels, and interpose a set of gearing which would allow this

action to take place, and at the same time drive the rear wheels at an equal number of revolutions when the vehicle was traveling in a straight line. There are two types of gearing which are commonly used for this purpose. One known as the "bevel gear differential," the other as the "all spur gear" type. In the former, or bevel gear type, two bevel gears are fastened rigidly, one at each end of the two axle shafts. Three bevel pinions, supported upon separate axles,

No. 1. No. 2.

FIGURE 128.

THE BEVEL DIFFERENTIAL.

No. 1 shows gear apart, No. 2, assembled.

which are pinned to the differential casing, mesh with both the larger gears. Now, when the vehicle is traveling straight ahead, the road resistance to each rear wheel is the same, and consequently none of the gears revolve, the small pinions acting as a lock on the whole system, the whole case and axle revolving as one piece. On the other hand, upon turning a corner, wheel A at once tries to slow down, and in doing so immediately causes the small pinions to revolve on their own axis with the result that they, being also in mesh with gear B, will cause it to revolve faster in the same ratio as A is slowing down, that is, the outside rear wheel

speeds up in the same proportion as the inside wheel slows down. A better understanding of this action may be gained by considering the homely example of the whiffle-tree of a wagon, which provides an equalizing device so that the pull on the pin is always the same.

In the "all spur type" the same result is obtained by a set of two large spur gears, one fastened to each section of the axle, and connected with each other through sets of two spur pinions arranged as shown in the illustration. The action of this type of differential is a little harder to understand, but you will find, after

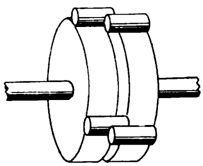


FIGURE 129.

DIAGRAM SHOWING LOCATION OF GEAR IN "ALL SPUR" TYPE OF DIFFERENTIAL.

studying it carefully, that the same result is obtained. A compensating gear is not required on the rear axle of a horse-drawn vehicle for the reason that in this case the carriage is caused to move by an outside force, and the wheels are free to accommodate themselves to any speed. In the case of the motor car, however, the moving power is applied through the rear axle, and the driving wheels are rigidly attached to it.

Of course, it does not matter where this compensating device is introduced as long as the result is obtained, and it may, therefore, be used as a part of the rear axle, or when a countershaft and side chain drive are employed, as a portion of the countershaft.

REAR AXLE CONSTRUCTION. The rear axle may be divided into two types, live axles and dead axles,

the former being used when the axle shaft is divided into two parts, and connected by a differential. The

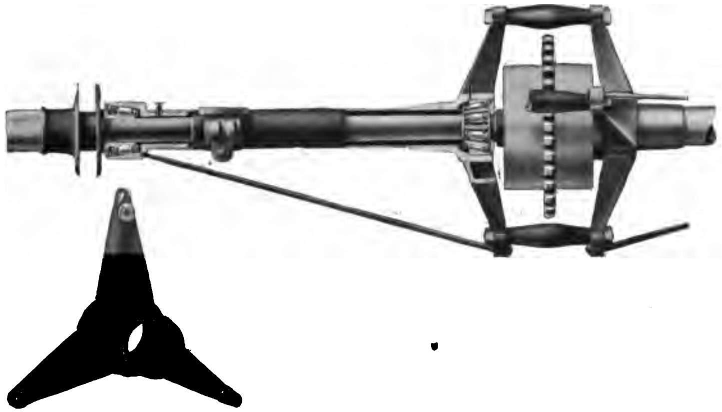


FIGURE 130.

VIEW OF HOUSING. CHAIN REAR AXLE.

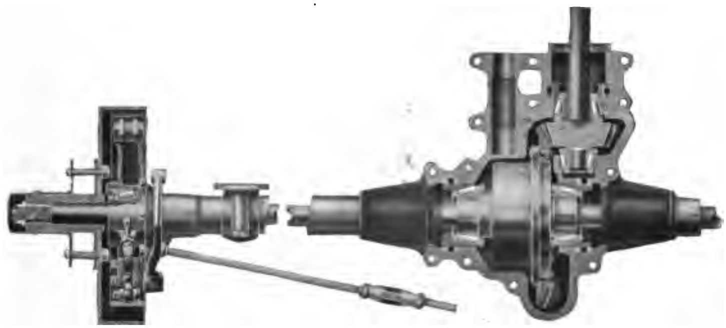


FIGURE 131.

Rear Vertical View. Horizontal View.

SHAFT DRIVE REAR AXLE.

rear wheels are rigidly connected to the axle shaft, and revolve with it. The axle proper is surrounded by a steel tubular casing which, in addition to affording a protection to the working parts, supports the bearings

in which the axle runs. The form and construction of this type of axle is clearly shown in Figs. 130, 131, 132.

The "dead type" of axle is made of steel tubing or

FIGURE 132.

Rear Vertical View. Horizontal View.

CLUTCH DRIVE OR FLOATING TYPE REAR AXLE.

of I-beam section, and is used in connection with the countershaft and side chain drive. It is solid its entire

FIGURE 133.

SOLID REAR AXLE WITH CHAIN DRIVE FROM COUNTER SHAFT.

length, and has bearings at each end upon which the wheels revolve. There are a number of different axles on the market, each with special features, such as special roller or ball bearings, ease of accessibility, and numerous types or re-inforcements.

THE FRONT AXLE. The front axles on all cars of standard design are of tubular or I-beam section, and are solid for their entire length. They are fitted with yokes at each end, in which are supported the spindles

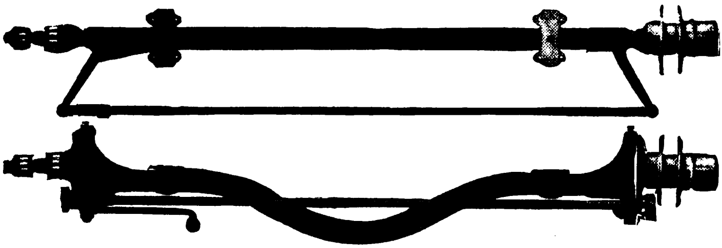


FIGURE 134—TUBULAR FRONT AXLE.

upon which the front wheels revolve. The front axle is very simple in construction, and therefore should require no further explanation.

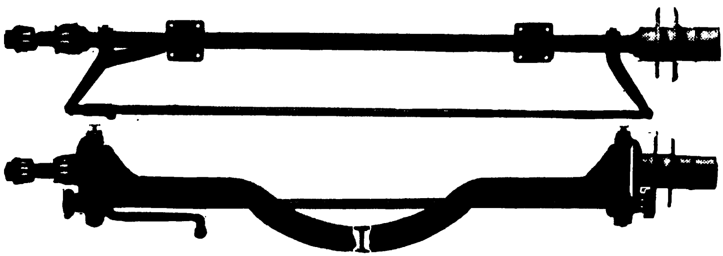


FIGURE 135—"I" BEAM FRONT AXLE.

STEERING GEAR. Various forms of steering gear have been used, but the only two that are employed to any great extent are the tiller and wheel systems. The tiller, or lever, steering gear, is very simple, and easy to operate, but owing to the fact that no system of worm gearing is used, it is not "irreversible." That is, it is affected by any movement of the wheels, and all

inequalities of the road affecting the front wheels are transmitted to the hand of the driver. Owing to its simplicity, however, it will always remain a very popular method of steering for light runabouts.

THE WHEEL STEER. There are numerous devices used in connection with wheel steering, the more common, however, employing the principle of the worm gear and segment, or screw and babbitt block. In each

FIGURE 136.

STEERING KNUCKLE, BEARINGS AND HUB.

case the turning effect of the wheel is converted into a backward and forward straight line movement (assumed to be this, but in reality the arc of a circle) which by means of a connecting link is communicated to the steering spindle of the front wheel. As each front wheel is mounted on an axis, and connected by means of a connecting rod with the other wheel, both wheels may be made to turn at the various angles required by revolving the wheel in one direction or another.

MOTOR TESTING

The actual testing of a motor car may be divided into three parts: First, the experimental testing, which is done largely to determine the brake horse power of the first engine of any model which is built. Second, the indoor try out to which the motor is subjected before being placed in the frame, and the final and most severe test—the running of the car over all sorts of rough roads and hills in order to make sure that the machine is absolutely reliable in every way.

INDICATED HORSE POWER. In order to better understand the action of the gases in the cylinder, engineers have devised various mechanisms for producing graphical representations of the conditions of working fluid during the different periods of its operation. The result was the "indicator card."

Let us first consider a gas enclosed in a certain volume,—a, b, c, d,—this gas we will say is at an atmospheric pressure (15 pounds per square inch), and occupies a volume of 120 cubic inches. Now, if we wish to represent this set of conditions we may do so in the following way: If O X represents a volume line and O Y a pressure line, then, if suitable units of pressure and volume are laid off on their respective lines, the above condition may be indicated by the point P, which you will see is made by the intersection of two lines, one drawn parallel to line O K through 120 cubic inches volume. Similarly P1, P2, P3, P4, and P5 represent to the eye volumes and corresponding pressures when the piston is respectively in position, 1, 2, 3, 4 and 5.

Now, if you draw a line through the five points we will have a line which shows the relation between the volume and pressure during the whole movement of the piston from position one (1) to position four (4), and consequently if a volume is known, the corresponding pressure may easily be found by dropping a perpendicular onto the pressure line from a point where a perpendicular directed from the known volume intersects this curve.

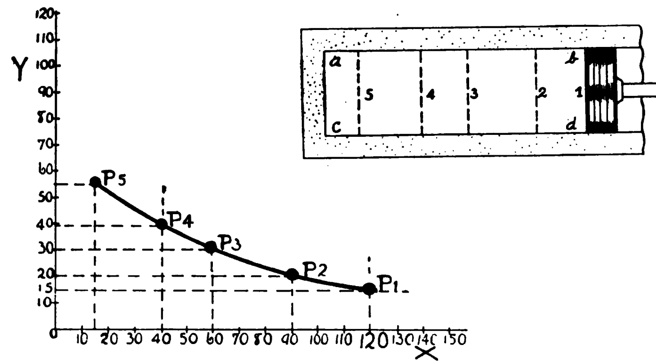


FIGURE 137—GRAPHICAL REPRESENTATION OF CORRESPONDING PRESSURES AND VOLUMES.

In other words, suppose we wish to find the corresponding pressure for a volume of 40 cubic inches: First erect a perpendicular at 40, and from the point where this line intersects the curve, drop a perpendicular on O Y. The point at which this line intersects O Y represents the desired pressure. You can readily see that if an apparatus could be devised which would make the engine draw these curves automatically, that the result would be a picture of just what was occurring in the cylinder at every portion of the stroke. (Of

course, you have probably realized that the curve which we have just plotted is practically the compression curve of the motor. The three other strokes may be plotted in the same way.) This is what is actually done.

THE INDICATOR. We will first study a simple form of the apparatus and see how this is brought about.

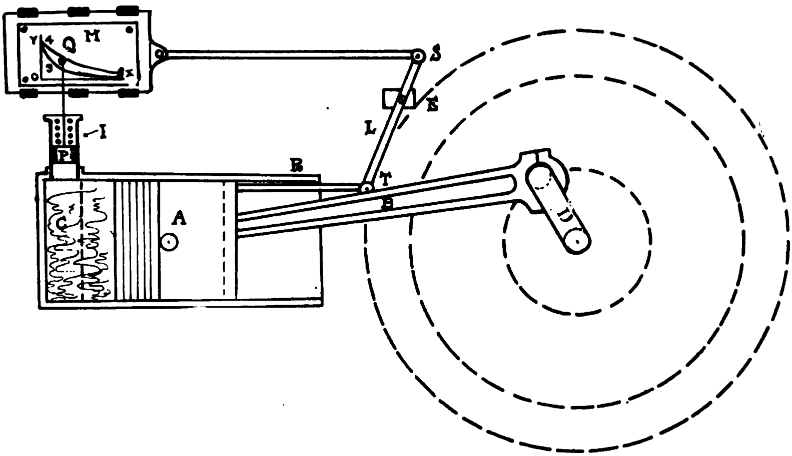


FIGURE 138—DIAGRAMMATIC SKETCH SHOWING METHOD OF OBTAINING A GRAPHICAL REPRESENTATION OF CONDITIONS INSIDE THE CYLINDER BY MEANS OF THE "INDICATOR."

C is a cylinder; A a piston working in same; D crank shaft; B the connecting rod; L a lever pivotted at E and operated by rod R fastened rigidly to the piston; M is a flat plate which may be moved horizontally back and forth, being kept in a straight line by guides along the top and bottom; I is a small tube screwed into the cylinder proper, inside of which moves a small piston P. On top of this piston is a rod fixed to it, and carrying a pencil at its upper end.

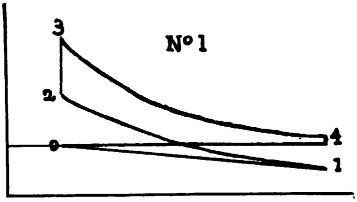
Let us suppose that the pressure in the cylinder is allowed to remain at atmospheric pressure, and that the piston moves back and forth in the cylinder, then you will see that if a sheet of paper is pasted on the plate M, and pencil point Q adjusted so that it touches the paper, a horizontal line will be drawn, the length of which is proportional to the stroke of the piston, this ratio being regulated by the length of the lever arm E T and E S, that is, if we assume that E S equals ½ of E T, then the line O X will be ½ the length of the pistol travel.

Now let us take the other case: If the piston remains stationary, and the pressure in cylinder is caused to rise by means of an explosion inside cylinder, then the small piston P in the pipe will travel up in a straight line, thus drawing the line O Y, which is perpendicular to the line O X.

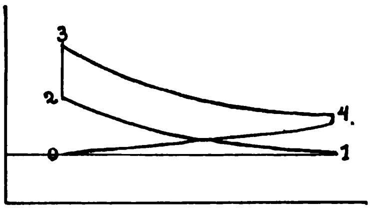
Having seen what happens when each quantity is allowed to vary independently of the other, let us see what effect changes of both volume and pressure will have upon the pencil point. If we consider the piston to be just starting upon the suction stroke, you will notice that the volume will continually increase until the end of the stroke is reached, the contents of the cylinder remaining practically at atmospheric pressure. This will produce the horizontal line O X.

Next, the valve on the cylinder is closed, and the piston is driven back against the gas. Consequently, as the volume decreases, the molecules of gas are crowded closer and closer together, and the pressure rises in some such proportion as that shown by curve 1-3. In the neighborhood of point 3 the ignition occurs, causing the pressure to rise to a pressure as

indicated by point 4. By this time the piston is in position to start back again on its outward working stroke; as the volume increases again the pressure drops back along a line 4-1 until at the end of the stroke, the pressure has been reduced to about 20 or 30 pounds. At this point the exhaust valve opens, and the return



No. 1—Card showing effect of throttling entering gases.



No. 2—Card showing effect of back pressure or delayed opening of exhaust valve

FIGURE 139—ENGINE INDICATOR CARD.
0—1 SUCTION STROKE. 1—2 COMPRESSION STROKE. 2—3 EXPLOSION OF GASES CAUSING RAPID RISE IN PRESSURE. 3—4 WORKING STROKE. 4—0 EXHAUST STROKE.

movement of the piston forces the burned gases out at atmospheric pressure along the line 1-0. This complete series of changes in the diagram just drawn represents to the eye the exact condition of affairs at every part of the whole operation.

As a matter of fact, the above apparatus is not used on account of not being practical or accurate. A modi-

fication of this, however, has been made and used extensively in gas engine testing work. Fig. 140 shows a view of one type of indicator. You will note that

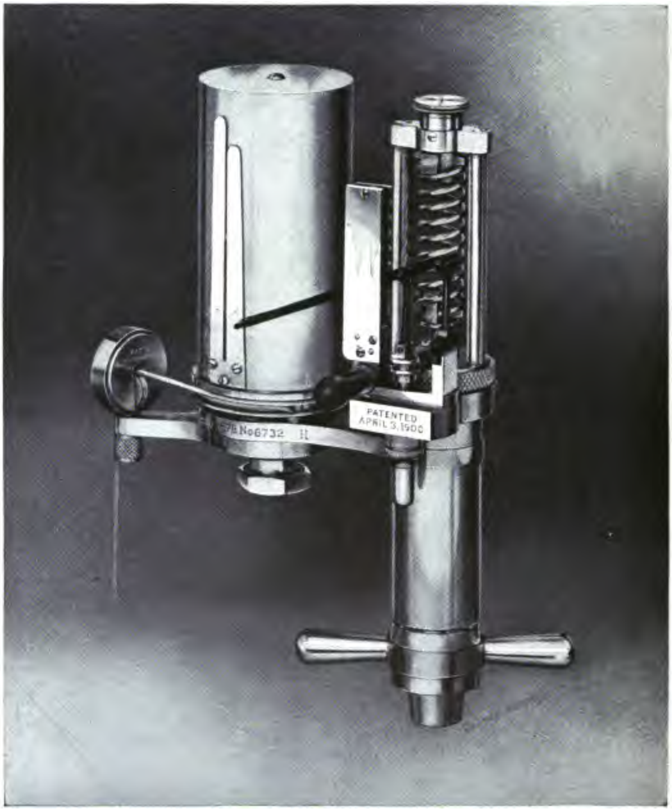


FIGURE 140—INDICATOR WITH OUTSIDE SPRINGS.

the paper instead of being put on a flat plate is placed on a drum, and the drum revolved by connecting a cord wound around it to some point on the engine which will give you a movement in the same direction and

proportional to that of the piston. The inside mechanism explains itself. The spring used to counteract the effect of the pressure on the indicator is calibrated so that each inch of compression represents a certain number of pounds per square inch. For instance, a sixty-pound spring would compress exactly one inch for every sixty pounds per square inch pressure in the cylinder.

A straight line movement transfers the up and down movement of the indicator piston to the pencil point, so that you see in principle the apparatus is simply a modification of the first mentioned system.

THE INDICATOR CARD. Now that we have the indicator card, you will ask what purpose it is to be used for? As an answer ask yourself a few questions like the following: How high is the compression pressure? What is the maximum pressure of explosion? Does the muffler produce back pressure? Are the valves opening properly? Is the motor developing all the power it should develop? The above are just a few of the questions which may be easily answered by an examination of the indicator card. Let us first see what effect each of these conditions would have upon the form of the indicator card. Suppose, for example, the inlet valve did not open a sufficient amount or that the incoming gases were throttled in some way, then you will readily see there will be a partial vacuum produced behind the piston, and consequently the pressure will drop below atmospheric as shown in No. 1 Fig. 139.

If the exhaust valve does not allow the gases to pass out fast enough, you will note that instead of the pressure dropping to atmosphere at the end of the stroke (4) it will not reach this pressure until part way on its

return stroke (4-1). This is also true if the muffler is so designed that it produces certain amount of back pressure, that is, if it does not allow the gases to escape into the atmosphere readily.

FIGURE 141—INDICATOR WITH OUTSIDE CONNECTING SPRINGS.

Both the compression pressure and maximum pressure may be found by measuring the distance from the volume line to the desired point on the curve, and multiplying this by the scale of the spring.

INDICATED HORSE POWER. All of this may be seen instantly from an indicator card, but in order to

find the indicated horse power it will first be necessary to take up the formula used.

$$I\ H\ P = \frac{PLAN}{33000}$$

P—Mean effect pressure in pounds per sq. in.

L—The length of stroke of piston expressed in feet.

A—Area of the piston in sq. in.

N—Number of explosions per minute.

The qualities A and L may be very easily measured. N is counted by means of a counter or some device which will register the exact number of explosions per minute. Of course, in the case of a two-stroke cycle of the ordinary automobile type the number of explosions and the number of revolutions will be the same, but in the case of the four-stroke cycle there are two revolutions for every one explosion. Motors of the "hit and miss" variety, that is, those which are governed by cutting out the ignition when the motor speeds up beyond a certain limit, must be taken care of by a special device which only counts every time an explosion takes place. Thus you see that with the exception of the "mean effective pressure" all the data necessary is easily found. The mean effective pressure is that pressure which, if it were to act upon the piston during the whole stroke, would produce the same effect as the varying pressure found in actual practice. That is, the piston might start with a pressure of 300 lbs. and reach the end of its stroke with only 50 pounds acting behind it. Suppose that it is found that the same work can be done by a constant pressure of 75 pounds acting during the whole length of the stroke. Then 75 pounds would represent the mean effective pressure.

One way of obtaining the mean effective pressure is to find the area of the card in square inches by means of a planimeter and divide the area by the length of the card in inches, which will give you its mean height in inches or "ordinate," as it is called. This mean height or "ordinate" multiplied by the scale of the spring will give the mean effective pressure. If a planimeter is not to be had, this mean ordinate may be determined in a very simple way, as follows: Divide the length of the card into ten equal divisions, and lay off each of the intercepted distances upon a long line. Then divide this line into ten equal parts, any one of which may be taken for the mean ordinate. By simply measuring the length of this "tenth part" of the line, and multiplying it by the scale of the spring used in the indicator, the mean effective pressure can be found.

For slow speed work the ordinary indicator gives very good results, but for high speed motors, such as those used in automobiles, it is necessary to use a more sensitive instrument. For this purpose there is now on the market an indicating device operated by electricity which by means of a set of mirrors may be made to produce an indicator card upon a blackened screen which may be studied or traced the same as ordinary pencil drawn record. Improvements are constantly being made along this line so that while it is not always convenient to take indicator cards from high speed motors, the same may be done, if necessary, by using these special instruments.

EXPERIMENTAL TESTING.* When the first car of any model is built the question at once arises: How many horse power will the engine develop? How shall we rate the car? Of course it is possible, knowing the

*Reprinted from article by author in Horseless Age.

cylinder bore and stroke, to determine practically the indicated horse power developed, but the brake horse power—the actual horse power delivered to the transmission shaft—cannot be so accurately calculated, and therefore can be much more easily determined by experiment. For this reason a miniature testing plant is installed in the experimental room where the engine is put through all sorts of tests to determine the horse power developed, mechanical efficiency, heat efficiency, average maximum speed, proper opening and closing of valves, and a thousand and one other things which the designing engineer must know.

Of course in this experimental testing everything is done to create actual conditions; that is, provisions are made to use the same kind of gasoline, air at practically the same temperature, lubricating oil of the same viscosity and fire test, and in general to keep the engine working under the same load and at the same speeds as in actual road work. In some cases the regular radiator and water system utilized in the automobile is used; in other cases the water from the city mains is used direct.

THE BRAKE TEST. In the first place, it is absolutely necessary to provide a strong foundation for our engine, for the reason that at certain times the engine will be "speeded up" to 1,500 or 1,800 r. p. m. Usually a special cast iron frame is made, which is well bolted down to a steel track imbedded in concrete. Next, the motor is placed in position, the various pipes for water and gasoline are connected up, and a Prony brake similar to that shown in the illustration is placed around the flywheel. The coil, batteries and wiring are next installed, and the engine is started. As soon as

it has run for twelve or fifteen hours, and the bearings are properly worked in, arrangements for the test are begun.

First, a calibrated gasoline tank, equipped with a glass measuring gauge, is substituted for the regular tank. Next the air supply of the carburetor is joined with the outlet pipe of an air meter—an instrument

FIGURE 142—TESTING A TWO-CYLINDER VERTICAL MOTOR.

Note the Prony brake and arrangements for determining the temperature and weighing the cooling water.

which will measure the number of cubic feet of air used per minute. A pyrometer, an instrument for measuring very high temperatures, is placed in the exhaust pipe. In addition to this, thermometers are placed at the inlet and outlet of the water cooling system, and a tub resting on a pair of scales is placed in a convenient position to weigh the amount of water which is used for cooling purposes. A Prony brake, with its accompanying pair of scales, a thermometer

to determine the room temperature, a gas analysis outfit and a calorimeter—an apparatus for determining

FIGURE 143—A CALORIMETER.

The apparatus used for determining the heat value of gasoline.

the number of heat units in the gasoline—complete the equipment.

Fig. 144 shows the general arrangement of this apparatus. First, the heat value or amount of energy in

a given amount of gasoline is determined by burning it in the calorimeter, one type of which is shown in Fig. 143. Next, the various thermometers and other instruments are calibrated to absolutely make sure that all readings will be correct. All the men who have charge of the tests are next informed as to their various duties, as to how and when readings are to be taken.

When everything is in readiness the motor is started, the initial readings are taken and recorded, and from that time on everything which happens is carefully noticed and a log kept of the whole test. If a great number of tests are to be made a book of ruled forms is made up similar to the page shown on 191. In addition to this the designing engineer, of course, has other data regarding the motor, but all the information required for determining the brake horse power, mechanical and heat efficiency is shown here. The quantity T_1 represents the temperature of the water before it goes into the cooling system; T_2 the temperature as it goes out; T_3 the exhaust temperature.

The number of pounds of water used can be easily determined by simply subtracting the weight of the tub from the total weight recorded on the scales.

The revolutions of the engine shaft are taken by a regular speed counter.

The pounds of gasoline used may be read from the calibrated glass gauge on the side of the gasoline tank.

Lastly, the pressure of the Prony brake on the other set of scales is noted, and this, minus the weight of the brake beam itself, will give the force exerted on the scale platform by the engine.

A sample of the exhaust gas is taken and analyzed

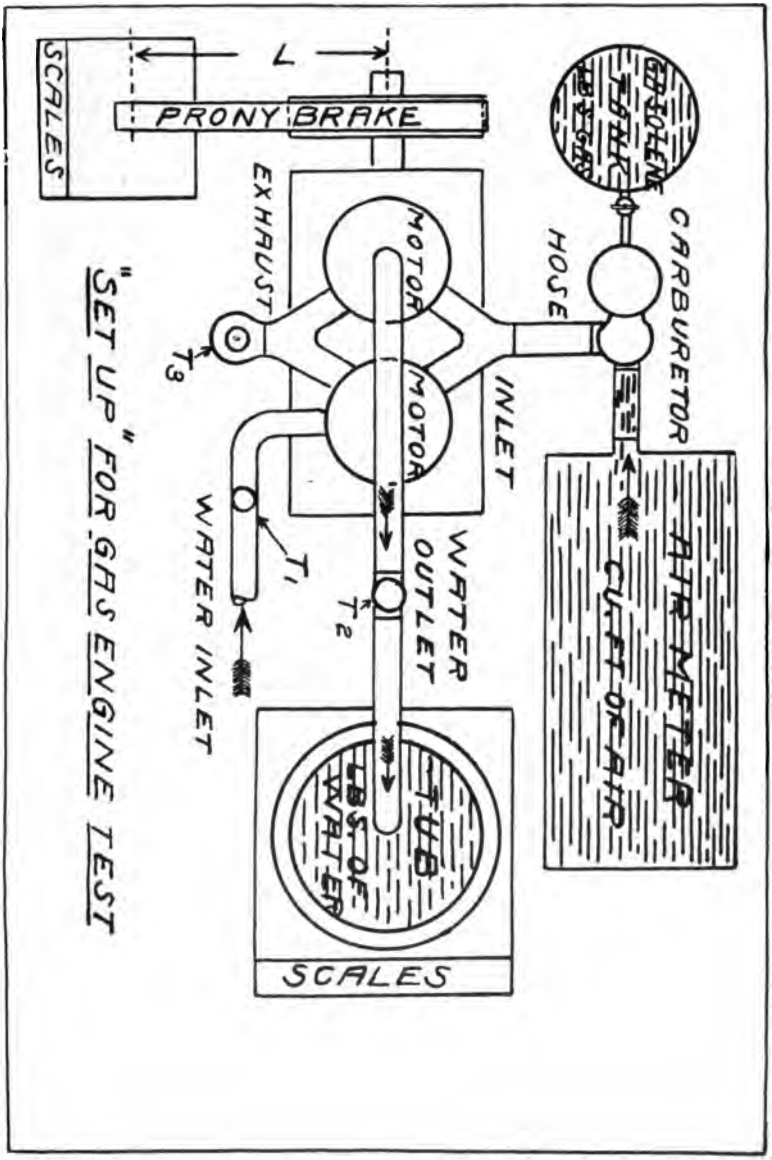

SCALES
L
PRONY BRAKE
CARBURETOR
HOSE
EXHAUST
MOTOR
MOTOR
INLET
T3
T1
T2
WATER OUTLET
WATER INLET
AIR METER
CU. FT. OF AIR
TUB
LBS. OF WATER
SCALES
"SET UP" FOR GAS ENGINE TEST

FIGURE 144.

by means of the Orsat apparatus shown in Fig. 145. This apparatus, by the way, consists of four glass bottles, one into which a known volume of the gas is admitted for analysis, the other three containing three combinations of chemicals, one of which absorbs carbon monoxide, the second oxygen and the third carbonic acid gas.

These various quantities will give us all the information necessary, so we will next look at the method of deriving practical results from this seemingly complicated data. Each test is figured out by itself, and the average results are used.

COMPUTATION OF RESULTS. Conduction Loss.—The amount of water used in cooling the motor may be taken directly from weights recorded.

The difference between T_2 and T_1 will give the rise in temperature of the water in passing through the system. Knowing the amount of water and its gain in heat the "conduction loss" can be easily computed, and will be equal to the gain in heat multiplied by the amount of water multiplied by the specific heat of water. The result which is obtained will be expressed in British thermal units (B. T. U.), but as there is a certain relation between horse power and heat units this result may be, if desired, transferred to horse power units. By way of explanation it might be well to add that the "British thermal unit" is the amount of heat necessary to raise 1 pound of water 1° Fahr., and one British thermal unit equals 778 foot pounds of work. One horse power equals 33,000 foot pounds of work per minute. The "specific heat" is the number of B. T. U. required to raise the temperature 1 pound of any substance 1° Fahr., or, in other words,

GAS ENGINE TEST—DATA TO BE OBTAINED.

Date, 3—1—'05. Name of Test. No. of Test, 1.

Engine Tested, 5 x 6 in. "B" Motor. Place Tested, Ann Arbor, Mich., U. of M.

No. of Test.	Time.	T_1.	T_2.	Exhaust Temperature.	Lbs. Wt. of Water.	R. P. M. of Shaft.	Lbs. of Gasoline Used.	Cu. Ft. of Air Used.	Weight on Scales.	B. H. P.	B. H. P. in B. T. Us.	Total Heat.	Conduction Loss.	Exhaust Loss.	Lbs. Gas Per B. H. P. Hr.	Per Cent Piston Displacement Filled.	B. H. P. in Per Cent.	Conduction Loss in Per Cent.	Exhaust Loss in Per Cent.	Radiation Loss in Per Cent.
1..............	1:30	49	162	550	....	181	..	....	40	3.6	....	......	....	....	..	..	....	....	....	...
2..............	1:40	50	169	545	35.5	194	.45	110	40	3.9	1,654	8,370	4,224	2,391	.70	48	19.8	44.3	31.2	6.5
3..............	1:50	48	160	555	34.0	200	.55	112	40	3.9	1,696	10,230	3,808	2,931	.82	47	16.6	44.3	31.2	6.5
4..............	2:00	47	174	555	36.0	196	.50	111	40	4.0	1,654	9,300	4,572	2,931	.77	47	17.7	44.3	31.2	6.5
5..............	2:10	46	167	545	33.5	195	.52	111	40	3.9	1,654	9,672	4,050	2,931	.80	47	17.9	44.3	31.2	6.5
Total..........	....	..	....	....	139	....	202	444	..	..	....	......	....	....	..	..	....	....		...
Average.......	....	48	166	550	34.7	193	.50	111	40	3.9	1,664	939.3	4,164	....	.77	..	18.0	....	....	...

Exhaust analysis..		In Per Cent.	Actual.
	CO_2.......	6.30	8.25
	O_2........	0.13	.17
	CO........	0.00	....
	H_2O......	23.93	....
	N........	69.64	91.58

Room temperature.
Barometer reading.

Brake constant = .0005
Heat value of gasoline = 18,600
Position of throttle =
Length of brake arm = 31⅛ in.
R. P. M. = 664 Ratio of sprockets =

Valve Timing.

Opening of exhaust..............58.69° early
Closing of exhaust............... 5.59° late
Opening of inlet..................16.77 late
Closing of inlet...................55.9 late

Timing of Spark.

Spark..............................30° early

the specific heat of a substance is the ratio between the amount of heat required to raise the temperature of the substance 1°, and the amount of heat required to raise the same weight of water 1°.

The gasoline used can be read from the graduated tank and the amount of air used direct from the air meter.

The brake horse power is equal to

$$B\ H\ P = \frac{2\ \pi\ W\ L\ N}{33000},$$

in which

$2\pi = 2x3.1416$.

W = weight on scales.

L = length of brake arm in feet.

N = number of revolutions per minute.

When running off the series of tests the length of a brake arm is, of course, always the same, and it is then possible to work out the $\frac{2\pi L}{33000}$ part of the formula, so it will be a constant, and we can then obtain the brake horse power very easily by multiplying this constant number by the number of revolutions and by the weight on the scales.

In order to reduce the brake horse power to B. T. U. it is only necessary to remember the relations:

1 B. T. U. = 778 foot pounds.

1 horse power = 33,000 foot pounds per minute.

The brake horse power multiplied by 33,000 multiplied by the duration of the test equals the total foot pounds developed, the foot pound being the amount of work required to raise the weight of 1 pound 1 foot from the ground against the force of gravity. Then the total number of foot pounds just computed from the

horse power developed may be converted into B. T. U. by dividing by 778.

HEAT VALUE OF GASOLINE. Having determined the heat value of the gasoline in a calorimeter and knowing the amount of gasoline used, we can calculate the heat supply by simply multiplying one amount by the other. Knowing the amount of gasoline used for the brake horse power developed during the test the amount of gasoline per brake horse power per hour is then easily found.

PER CENT OF PISTON DISPLACEMENT FILLED. The amount of piston displacement filled is completed by first figuring the total volume of the cylinder when the piston is at the outer end of the stroke. This is expressed in cubic inches. Then, as the number of revolutions divided by two—for this is a four stroke engine which we are testing—gives the number of times this volume is filled in a minute, the total volume to be filled in a minute is equal to the product of the piston displacement multiplied by half the number of r. p. m. Then if this product is multiplied by the time required to complete the test this will give the total volume to be filled. Then from our log we find that only a certain amount of air has been used. The amount of gasoline being almost negligible, the number of cubic feet of air used, divided by the total volume to be filled, equals the per cent of piston displacement volume filled.

EXHAUST LOSS. In order to compute the amount of energy which is lost by passing through the exhaust pipe in the form of heat, it is first necessary to know the percentage of carbon dioxide, oxygen and nitrogen

in the exhaust gases. Let us assume, for instance, that a certain analysis is as follows:

Carbon dioxide (CO_2)	8.25%	
Oxygen (O_2)	.17%	
Nitrogen (N)	91.58%	(by subtraction)
	100.00%	

The method of catching samples of exhaust gases under water necessarily condenses the steam, and therefore it does not show up in the analysis. For this reason the values obtained from Orsat's apparatus are slightly inflated. The volume of nitrogen does not change, neither does the volume of free nitrogen. The carbon dioxide (C_2O) occupies the same volume as the oxygen (O_2), which went to form it. Water (H_2O) as steam occupies twice the volume of the oxygen (O_2) of which it is composed. Since the steam in the exhaust has been condensed, the exhaust gases occupy a smaller volume, and therefore the volumes of nitrogen, oxygen and carbon dioxide will each be a greater percentage of the whole than if the water was present. Air is composed of 79.1 per cent of nitrogen, and 20.9 per cent of oxygen by volume. The analysis above shows that out of 100 volumes of exhaust gas analyzed there were 8.25 volumes of carbon dioxide and .17 volume of free oxygen, the balance, 91.58 volumes, being nitrogen. These 100 volumes of exhaust gas, however, did not include the water, which came through in the form of steam. Since there were 79.1 volumes of nitrogen in the 100 volumes of air which went into the engine and none of it was lost or changed, the per cent shown by the Orsat apparatus is too large by a ratio $\frac{91.58}{79.10}$. Now if we reduce the

volumes of carbon dioxide and oxygen in the same ratio we have, out of the 100 volumes put into the motor,

Oxygen to form CO_2	7.15 vols.	
Oxygen as free O_2	.15 vols.	
Oxygen to form H_2O	13.60 vols.	(by subtraction).
Oxygen 20.9.	20.9 vols.	
Nitrogen 79.1.		

FIGURE 145—THE ORSAT APPARATUS.

Beginning at the left the first bottle contains cyprus chloride which absorbs carbon monoxide. The second, potassium pyrogallat, which absorbs oxygen. The third contains potassium hydrate, which absorbs carbon dioxide.

Since water (H_2O) as steam occupies twice the volume of the oxygen (O_2) which helped to form it, it will be seen that the 100 volumes of entering air have been separated as follows:

Nitrogen	79.1 vols.
Oxygen	.15 vols.
Carbon dioxide	7.15 vols.
Water	27.20 vols.
	113.60 vols. of exhaust gas.

Knowing now the constituents of the exhaust gas and their temperatures at the moment of the opening of the exhaust valve, and their specific heats at this temperature in small calories per litre (Le Chatelier's determinations), we can find the heat units lost in exhaust.

Constituent.		Temperature.		Specific Heat.		
Nitrogen	79.1 ×	550 ×		.331 =		14,400
Oxygen	.15 ×	550 ×		.331 =		27
Carbon dioxide	7.15 ×	550 ×		.473 =		1,690
Water (H_2O)	27.50 ×	550 ×		.416 =		6,230
Total						22,347

small calories per 100 litres of air, or 223.47 small calories per 1 liter of air.

During a ten minute run there were 110 cubic feet of air metered to the engine.

One small calorie per litre equals .11236 B. T. U. per cubic foot. Then if we multiply 223.47 by 110 by .11236, we will have the result in B. T. U. = 2,764 B. T. U. After all the results are computed, in order that the various quantities may be used readily, each quantity is reduced to per cents. The following table shows how these percentages are derived:

$$\text{B. H. P. in \%} = \frac{\text{B. H. P. in B. T. U. (1654)}}{\text{Total B. T. U. (8370)}} = 19.8.$$

Conduction Loss in % =

$$\frac{\text{Conduction Loss in B. T. U. (4224)}}{\text{Total B. T. U. (8370)}} = 44.30\%.$$

Exhaust Loss in % =

$$\frac{\text{Exhaust Loss in B. T. U. (2764)}}{\text{Total B. T. U. (8370)}} = 33\%.$$

Radiation in % = balance assumed to be radiation = 3%.

In addition to this the various tests are averaged and curves plotted which show how these quantities vary under different conditions of load and adjustment.

The above work looks rather complicated, and, in fact, such a test is no small undertaking. It is absolutely necessary, however, if one is to know exactly what a certain motor is doing, but need not be repeated until some radical change is made on some part of the engine which will affect these conditions.

MOTOR TESTING IN THE FACTORY. As soon as an engine has been developed by the experimental engineer and pronounced ready to be turned into the shop as a commercial proposition, it is no longer necessary to submit it to such exhaustive tests. It is, however, run under all sorts of conditions and long enough to show up any defects in construction, workmanship or adjustment.

As soon as a motor is assembled, and before the carburetor, spark plugs and other attachments are added to it, it is bolted to the foundation and run for several hours from a countershaft. This is done in order to "run in" the bearings and "work in" the piston rings and cylinder. The engine during all this time is kept flooded with oil, and all the bearings are carefully watched to keep them from overheating. After several hours of this work it is taken from the frame, the bearings are examined and readjusted, and the motor is then turned over to the indoor testing room.

INDOOR TESTING ROOM. This department of the motor car factory is generally placed some distance from the main building, and should be built almost en-

tirely of steel and concrete. There are generally two sets of tracks, one on each side of the building. To these tracks the testing frames are bolted and an overhead crane supported from the walls is provided, by means of which the "green" motors coming in at the

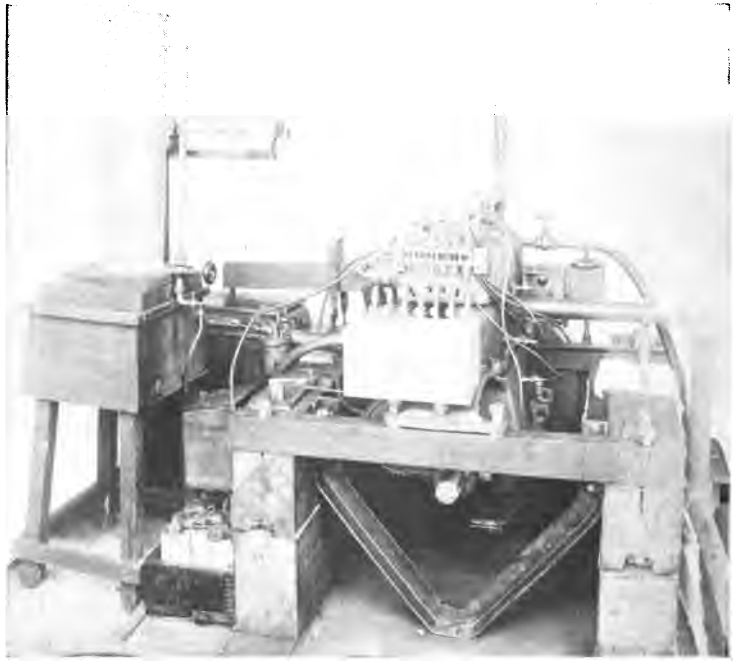


FIGURE 146.
ANOTHER VIEW OF THE TWO-CYLINDER MOTOR SHOWING THE CALIBRATED GASOLINE TANK, LUBRICATOR AND IGNITION.

front door may be quickly and easily placed upon any one of the frames.

Each motor testing frame is provided with its own belt for starting, its own coil, batteries and electric wiring, water pipes, through which the cooling water is forced, its own gasoline tap and its own exhaust

pipe. There is generally one main gasoline reservoir located on each floor, from which the small gasoline mains or small gasoline tanks, whichever the case may be, may be filled. The engines are carefully bolted on the frames, belted up to a jack shaft, and after being run for a little while are finally allowed to start out under their own power. They are allowed to run under

FIGURE 147—THE INDOOR TESTING ROOM.

various conditions of load, and at different speeds, until all the knocks and pounds are out of them and the whole engine runs easily and quietly. Sometimes it is necessary to spend several hours making proper adjustments, but the men never give up, and it is not until the motor is absolutely immune from all troubles common to its species that it is allowed to pass on to the next department.

OUT OF DOORS TESTING. It is not until the car reaches the "tester" that one feels that it is safe to predict what a certain engine will do, for it is here that it gets some of its roughest treatment. It is here that it is made to do everything which can reasonably be expected of it, and considerably more. Unless one

FIGURE 148.
TESTING A SINGLE CYLINDER MOTOR. (Note air meter on right.)

has been connected with an automobile factory it is hard to form an idea of the amount of testing which is done in order to "try out" a car. Several of the large concerns throughout the country have constructed tracks specially for this work.

The chassis are fitted with a single seat and then turned over to the "testers" for their final trial. These men, who drive continuously, put the car

through every known test, driving it at top speed for several minutes, and then stopping it immediately, climbing steep inclines, both on forward and reverse gear, running the car over embankments, ploughing through muddy roads so deep that sometimes the axles scrape, and in general doing their best to loosen up or break any part which is liable to prove defective.

FIGURE 149—"RUNNING IN" THE MOTORS.

Engines are run for several hours from a jack shaft in order to limber them up before sending them to the indoor testing room.

Oftentimes it is necessary to tear down the entire machine and rebuild it. The men understand that the machine is to be in perfect running order when it is turned into the shipping room, and therefore they continue making adjustments until the machine is as perfect as their expert knowledge and time can make it. The chassis is then returned to the paint shop, where the body is fitted, the old testing wheels are exchanged for new ones, and the regular equipment is added.

THE HEAD INSPECTOR. As a final test, the car is turned over to the head inspector, who drives the car

around the track, watching with an eagle eye every move of the mechanism, straining his ear for any knocks or pounds or grating sounds which might indicate faulty workmanship or imperfect adjustment, and using his "motor intuition" to determine whether or not the car is as near perfection as it should be. He finally takes out a card, and with it to check by

FIGURE 150.
TESTING ON INCLINE. HILL-CLIMBING ABILITY AND POWER OF BRAKES.

goes over the car from radiator to its rear axle, noting the condition and adjustment of bearings, wheels, control levers, brakes and a thousand and one little things which he knows can go wrong. He turns the motor over to see if it starts easily, looks at the gasoline connections, notes the carburetor adjustment, tries the compression of the motor, tests the adjustment of the coil, tries the steering gear to see whether it has developed any "lost motion," searches for bolts which are not cottered or locked, goes over the lubrication

system, checks up the wiring, scans the motor, transmission and frame for defective material, looks for leaks in the tanks or piping, tries the adjustment of the clutch, and finally looks over the body and upholstering to see if he can discover any defective workmanship or careless handling. If he is at last satisfied he O. K.'s his checking card, turns it in and delivers the car to the shipping room.

FIGURE 151.
TESTING OUT A FOUR-CYLINDER CAR AT 55 MILES AN HOUR ON A HALF MILE TRACK.

Notwithstanding all these precautions, automobiles are continually going wrong, and people curse the manufacturers for putting out what they call bad products. But is it any wonder? An automobile is required to do more work with less attention than any other piece of machinery used in the commercial world. Even a big locomotive has its steel tracks to run on, its competent engineer and fireman, and its careful handling and inspection after each of its limited trips. Not so with the motor car; it must be ready

to go at any time, travel over all sorts of roads, up and down mountains, many times driven by a person who knows simply that one position of the lever makes it go forward and the other backward.

It is to be hoped that with the assistance of the motor papers and the much improved literature which is now being circulated the general public will be educated to a point when a motor car will receive proper consideration, and the work of the manufacturer, who is spending a large amount of his money and time in perfecting his machine, will be more appreciated.

INDEX